UNITED STATES DEPARTMENT OF AGRICULTURE

Utilization of the Waters of Mojave River, California

By

HARRY F. BLANEY
Irrigation Engineer

PAUL A. EWING
Irrigation Economist

A Contribution From

BUREAU OF AGRICULTURAL ENGINEERING—S. H. McCRORY, CHIEF

DIVISION OF IRRIGATION—W. W. McLAUGHLIN, CHIEF

August, 1935

United States Department of Agriculture

UTILIZATION OF THE WATERS OF MOJAVE RIVER, CALIFORNIA

By

Harry F. Blaney
Irrigation Engineer

Paul A. Ewing
Irrigation Economist

A Contribution From

Bureau of Agricultural Engineering - S. H. McCrory, Chief

Division of Irrigation - W. W. McLaughlin, Chief

August, 1935

TABLE OF CONTENTS

SUMMARY

Mojave Valley is wholly in San Bernardino County, California, and the Great Basin of the United States. Barstow, the largest town, is 150 miles east of Los Angeles. The rural people are nearly all American-born, but many Mexicans work on the railroads. The valley has only two towns of importance, but only one-sixth of its approximately 6,600 persons live either on the farms or outside these towns and the other centers.

Total annual precipitation is very low; humidity is also low; high temperatures occur in summer, and the daily range of temperatures is wide. Strong winds occur in certain seasons. Barstow's elevation is 2,105 feet, and its growing season averages 245 days, but sections farther west and south have higher elevations and shorter growing seasons.

Electric power is available for domestic and irrigation use west of and including Barstow. Transportation facilities are exceptionally good. Alfalfa, dairy products, turkeys, and a few poultry products are the only agricultural commodities marketed to important extent outside the valley.

The valley area under consideration consists of the recent flood plain of the river and the alluvial terraces bordering it. A summary of the agricultural value of the soils made as a result of official surveys covering 363,000 acres, shows less than 1 percent first grade; 14 percent second grade, 45 percent third grade, 14 percent fourth grade, 18 percent fifth grade, and 9 percent sixth grade.

The valley's agricultural history has extended over 70 years, but the present development is the result of individual, not community or group effort, notwithstanding the hundreds of thousands of dollars which have been spent by various agencies. Pumping from wells has almost entirely displaced the earlier methods of irrigation involving gravity diversion from the river. A gradual growth has taken place in the last five years, although the present irrigated area is still less than that reported in 1917.

The valley is not heavily burdened with community obligations.

Between 1930 and 1935 the number of farms increased about 35 percent. The cropped area also increased by more than one-fourth, and is taken to be 6,000 acres. The land in operating farms which is available for crops is about double this acreage.

Alfalfa is estimated to account for about 90 percent of the cropped area. Fruit, notably apples, which 15 years ago gave promise of playing an important part in the valley's agriculture, has lost that promise principally because of low prices and the expense of pumping in the sections best fitted to it otherwise. Alfalfa acreage has more than balanced the decline of the fruit acreage. Exceptionally high yields of alfalfa are obtained, and sales are made at premium prices because of excellent quality.

The future of the hay industry is clouded, however, by the short life of stands caused by little-understood diseases now widely current in the State, and authorities see no likelihood that good producing stands can be maintained for more than four or five years.

Dairying is of present limited importance, and proposals looking to its expansion face the difficulty of breaking into the Los Angeles market. Poultry production has some promise, especially if the growing of grain should develop into greater importance by reason of crop-rotation necessities. The advantages attached to present specialization in hay-growing appear, however, to presage that alfalfa will continue to be the valley's principal crop for many years to come, although it is not now much more than repaying its cost of production.

The average value of farm dwellings is close to the State average; the value of all buildings is a little above, and the value of farm implements and machinery somewhat higher than the corresponding State averages, notwithstanding the fact that few tractors are operated, horses and mules being used instead. Most of the farmers do the greater part of the farm work, the farms being small (in point of cropped acreage) and mostly owned by their operators. Farm values are fairly high, but have declined severely during the past five years. The total value of farm land and buildings is in excess of $3,000,000. The farm mortgage situation has been somewhat relieved of late by refundings made through the Federal Land Bank.

The water in the upper part of Mojave River Basin is remarkably pure and well-suited to irrigation use. In the lower portions of the Basin it is not quite so good.

Most of the irrigated land in the valley lies adjacent to the river or in territory served by underflow from the same source. Usually the quantity of water applied for alfalfa ranges from six to nine acre-feet per acre per year, although on some farms quantities as high as 12 acre-feet have been applied. Where five or more acre-feet per acre is used in irrigation of alfalfa, most of the quantity above three acre-feet passes below the root zone to the underground basin as return water. The amount of water applied for crops other than alfalfa usually does not exceed three acre-feet per acre annually.

Most of the water used for irrigation in Mojave Valley is pumped. Present irrigation systems represent somewhat heavy outlays in wells, pumps, reservoirs, and pipe lines, but pumping lifts are fairly low. From the meager records available, the annual cost of electric power during 1934-35 for pumping ranged from approximately $6 to $22 per acre and $0.57 to $6.97 per acre-foot, the lower costs being for a 21-foot lift and the higher for a 262-foot lift. The cost per acre-foot per foot of lift ranges from 2.7 cents to 4.5 cents. The overall efficiency of the pumping plants varies from 44 to 58 percent. Data were not available to cover other items, such as interest, taxes, insurance, depreciation, repairs, etc., which enter into the cost of pumping, but it is estimated that the total cost of pumping ranges from $10 to $15 per acre per year.

The principal supply of Mojave River comes from 217 square miles of mountain headwaters which constitute the chief drainage system of the northern slopes of the San Bernardino Mountains. These headwaters comprise two distinct branches, East Fork or Deep Creek, and West Fork, which unite at the base of the mountains to form the main river. This junction is known as the Forks. The headwater region above the Forks, forms a collecting area for both the surface flow of Mojave River and a large part of the groundwater of the valley. Below the Forks there is a series of underground reservoirs. Where the water table is not at the surface, the stream percolates into its bed to appear as rising water lower down. These natural underground reservoirs regulate the water supply by accumulating and storing the water of wet years for use in dry periods. This cyclic storage is a valuable asset to the development of Mojave Valley, but thus far has not been fully utilized.

The average annual discharge of Mojave River from the mountains through the main river below the Forks is estimated as 90,000 acre-feet, while the increment from ground-water flow below Victorville is estimated to approximate 7,000 acre-feet; or together a total water supply of 97,000 acre-feet per year. During a 12-year dry period, 1922-23 to 1933-34, the run-off averaged 46,000 acre-feet per year, while during the 17-year period 1905-06 to 1921-22 the average stream flow is estimated to have been 122,000 acre-feet annually.

There is no existing problem in Mojave River Valley of failing underground water supplies. After a long period of subnormal run-off the water table has fallen only slightly in most areas and in some instances has risen in recent years. Good wells are readily secured in most areas adjacent to the river and pumping lifts are not great except on the mesas above the river.

Of the total average annual supply of water (97,000 acre-feet) considered as available for the valley, it is estimated that approximately 1,100 acre-feet is consumed by towns, railroads, and industries, 18,000 acre-feet by agricultural crops, and 39,000 acre-feet by native vegetation, leaving a balance of around 39,000 acre-feet, a large portion of which would be available for additional development provided it were economically feasible. The results of a diversion to the Santa Ana Basin or development of additional acreage in the Mojave Valley would, if extensive, bring about a considerable change in the regimen of the river. It is apparent that any large development of the water resources of the Mojave River must contemplate utilization of underground reservoirs as well as surface reservoirs.

The idea of diverting water not used beneficially, from the Mojave watershed to the south side of the mountains has been discussed at various times and in the interest of various localities. The proposal which led to the authorization of the study now being reported contemplates the use of Forks (West Fork) reservoir site (capacity 112,000 acre-feet) a diversion tunnel to carry water thence to the vicinity of Devils Canyon (north of San Bernardino) a power development there which would be expected to defray a part of the total cost

of the project, and a distribution system by which the water would be made available in equal amounts to the three counties of San Bernardino, Riverside, and Orange. The dam at Lake Arrowhead would be raised and the lake used as a regulating reservoir with some storage.

Plans for the transmountain diversion are as yet entirely on paper. Such as they are, they appear to indicate feasibility if judged solely on an engineering basis. However, before being entered upon they should be supported by detailed surveys, including careful explorations of proposed reservoir and dam sites. The economic feasibility of the expenditures then estimated to be necessary should be adjudged on the basis of water costs carried at the time by water users in Santa Ana Basin, taking into account such salvage requirements as may then exist.

Recent important court decisions have simplified the legal obstacles which heretofore have prevented transmountain diversions of Mojave River water, but the fact that the area claiming or in position to claim rights to it is much larger than the area which it could actually serve appears to recommend that an adjustment of the rights be obtained before any costly, large-scale development is undertaken.

Cost of water for irrigation in Santa Ana Basin runs from $10 to $15 an acre-foot and water for domestic and industrial use in the cities costs two or three times that amount.

CONCLUSIONS

The water supply of Mojave Valley is more than sufficient for the uses to which it is now put. Future agricultural development of the valley appears to lie along the lines of past growth; that is, by individual effort. An approximate doubling of the present irrigated area may be anticipated to result from such gradual expansion if it be undisturbed. This growth would probably be accompanied by a substantial increase in the present consumptive use of water by crops and to some extent a curtailment of the consumptive use by native vegetation. Alfalfa will probably continue to be the principal crop, deciduous fruits now holding little promise of future importance. The possibilities of dairying, poultry raising, and truck growing are at present limited, and a general reluctance on the part of the farmers to a change in the concentration upon hay-growing should be taken into account in any plans for large-scale development, notwithstanding the fact that the profits in hay-growing are now small.

Considering an equalizing series of years, a diversion of 40,000 acre-feet annually away from the Mojave River watershed apparently would not curtail the present irrigation use of water between the Forks and Victorville; it would produce some deficiency between Victorville and Barstow, and almost certainly a substantial deficiency below Barstow; but if the water table can be lowered without reaching an uneconomical

pumping level, the deficiencies might be made up from water stored underground and the resultant decrease in use by native vegetation. However, unless a substantial portion of the so-called non-beneficial use were corrected, no more than 15,000 to 20,000 acre-feet could safely be diverted across the mountains. If the agricultural use were confined entirely to the area above Barstow, 25,000 to 30,000 acre-feet apparently could be taken out without curtailment of present irrigation consumptive use.

Any diversion of Mojave River water outside its watershed should be made only after care is taken of the normal agricultural, domestic, and industrial needs (including those of railroads) of the valley itself. The valley's rights should stand in the preferred position and outside claimants should be satisfied with what is left. Hence, provision should be made to protect the present water needs of the valley before the diversion elsewhere is begun in any year.

There are no present legal obstacles in the way of a diversion, by appropriation, from one watershed to another in California. Riparian owners are limited to the watershed if they rely on their riparian rights. The new State doctrine, however, not only protects the actual reasonable beneficial use of the riparian, but also his prospective reasonable beneficial use; and a user of ground water underlying his land has a right correlative with other overlying land owners to make a reasonable use of the common underground supply. There is no general rule as to just what lowering of ground water constitutes an injury; mere lowering of the water plane is not in itself a wrong.

Whether or not present costs of water in Santa Ana Basin could be exceeded would apparently depend upon degrees of necessity and upon the other costs affecting the agricultural and other industries of the Basin.

INTRODUCTION

This is a report by the Division of Irrigation, Bureau of Agricultural Engineering, United States Department of Agriculture, dealing with the general subject of the utilization of the water of Mojave River, California.

Authorization

The study upon which the report is based was authorized by Henry A. Wallace, Secretary of Agriculture, as a result of an appeal addressed to him by twenty-five southern California municipalities and water companies. Their letter follows:

"Riverside, California,
April 17th, 1935.

"Honorable Henry A. Wallace,
Secretary of Agriculture,
Washington, D. C.

"Dear Sir:

"The undersigned organizations, through their respective officials, whose names are attached hereto, without obligation to any organization, respectfully request your cooperation, through qualified existing governmental organizations, to make an economic study of the Mojave River in the County of San Bernardino, State of California, with a view to planning a means of conserving all surplus water of said river over and above the amount now being put to beneficial use by property owners in the Mojave River valley, who have prior rights to the use of the Mojave River water.

"The purpose of this study and survey would be to ascertain the amount of water, if any, which can be stored in reservoirs of the Mojave River watershed, the means of conveying the said water to the south side of the San Bernardino Mountains into the watershed of the Santa Ana River and its tributaries, to augment the supply of water from the latter river now being used for domestic purposes to supply approximately 400,000 people, and to augment the supply of irrigating water used on approximately 350,000 acres of highly cultivated and productive agricultural and horticultural lands. The supply of water available from the latter watershed from gravity flow was formerly sufficient for all purposes, but with the increase of population and irrigated areas the water supplies are now inadequate and the underground water level is receding at an alarming rate; in fact, some communities in this area are faced with the problem of securing additional water or reducing the acreage or restricting increased population.

"Your petitioners will be very grateful for any assistance which you can render and will cheerfully furnish you with all available data relating to the problems hereinbefore referred to."

"Respectfully,

"GAGE CANAL COMPANY, RIVERSIDE, CALIF., Arthur S. Holden, President; RIVERSIDE WATER COMPANY, RIVERSIDE, CALIF., Francis Cuttle, President; CITY OF RIVERSIDE, CALIFORNIA, E. B. Criddle, Mayor and President of Board of Public Utilities, RIVERSIDE HIGHLAND WATER CO., RIVERSIDE, CALIF., D. S. Bell, President; LA SIERRA WATER COMPANY, RIVERSIDE, CALIF., R. H. Fuller, Secretary-Treasurer; SAN ANTONIO WATER CO., UPLAND, CALIF., W. K. Beattie, President; CITY OF SAN BERNARDINO, CALIF., J. W. Catick, President of Water Board; CITY of FULLERTON, CALIFORNIA, William L. Hale, Mayor; CITY OF ANAHEIM, CALIFORNIA, Chas. H. Mann, Mayor; ORANGE COUNTY WATER DISTRICT, ORANGE CO., CALIF., Willis H. Warner, President; SANTA ANA VALLEY IRRIGATION COMPANY, A CORPORATION, SANTA ANA, CALIF., A. N. Sexton, President; THE IRVINE COMPANY, TUSTIN, CALIFORNIA, James Irvine, President; SERRANO IRRIGATION DISTRICT, CALIFORNIA, Willard Smith, President; CARPENTER IRRIGATION DISTRICT, D. G. Evans, President; NEWPORT MESA IRRIGATION DISTRICT, C. W. Fendwinkle, President; CITY OF HUNTINGTON BEACH, CALIFORNIA, T. B. Talbert, Mayor; CITY OF ORANGE, CALIFORNIA, C. J. Hessel, Mayor; CITY OF NEWPORT BEACH, CALIFORNIA, Herman Hilmer, Mayor; CITY OF LAGUNA BEACH, CALIFORNIA, Frank Champion, Mayor; CITY OF SANTA ANA, CALIFORNIA, Fred C. Rowland, Mayor; ANAHEIM EUCALYPTUS WATER COMPANY, ANAHEIM, CALIF., L. L. Bruns, President; YORBA LINDA WATER COMPANY, YORBA LINDA, CALIF., A. B. McDavid, President; SANTA ANA RIVER DEVELOPMENT COMPANY, SANTA ANA, CALIFORNIA, John C. Tuffree, President; ANAHEIM UNION WATER COMPANY, ANAHEIM, CALIF., H. H. Hale, President; TEMESCAL WATER COMPANY, CORONA, CALIFORNIA, Joy G. Jameson, President."

Secretary Wallace's reply, addressed to Mr. Francis Cuttle, who had acted as agent of the signers of the above-quoted letter, was as follows:

"May 6, 1935.

"Mr. Francis Cuttle,
Room 324,
Mayflower Hotel,
Washington, D. C.

"Dear Mr. Cuttle:

"Careful consideration has been given to your communication of April 19 which transmits a request from the Gage Canal Company and twenty-four other municipalities and water companies of the Riverside area requesting that the Department make a study of the economic feasibility of storing surplus water on the Mojave River watershed and diverting it to the Santa Ana watershed for use in

that area. From the facts set forth in the communications accompanying your letter, it would seem that impartial investigation of this problem was desirable.

"The Bureau of Agricultural Engineering of this Department has given consideration to the matter and can arrange to undertake such an investigation and to assign to it two of their most experienced men, Mr. Harry F. Blaney, Irrigation Engineer, and Mr. Paul A. Ewing, Irrigation Economist, on condition that the interested organizations will arrange to take care of necessary incidental expenses in connection with the investigation which, it is estimated, will not exceed $2500. If this arrangement will be satisfactory, the details of the undertaking can be worked out with the representatives of the Bureau of Agricultural Engineering."

"Sincerely,

"(Signed) HENRY A. WALLACE

"Secretary."

Scope and Responsibility

The survey ordered by Secretary Wallace was started by Mr. H. F. Blaney and Mr. P. A. Ewing on May 22, 1935. Their first efforts were confined to the subject specified by the Secretary (i.e., the economic feasibility of storing surplus water on the Mojave River watershed and diverting it to the Santa Ana watershed for use in that area), but as their investigation progressed it developed that various controversial matters were involved and several State, county, municipal, company, and individual agencies concerned. To make the study entirely impartial and sufficiently comprehensive necessitated consideration of features not contemplated by the users of water in the Santa Ana area. It was therefore decided, with the approval of Secretary Wallace, that the Bureau of Agricultural Engineering should bear the entire cost of the investigation and that the employees assigned to it should receive no part of their salary or expenses from any other agency. Hence, the signers of the letter of April 17 were not held to the financial support specified in the Secretary's letter. However, since the available funds and the time of the investigators were limited, the Bureau undertook to complete the study within the period (three months) which had been estimated for it as first planned. Accordingly, the field work was closed about the middle of June, and the remainder of that month and all of July were spent in the preparation of this report.

Acknowledgments

Completion of so comprehensive an investigation in so brief a time was possible only by reason of the availability of the many data dealing with Mojave River and its valley which had been assembled by other agencies and the direct assistance given the authors by many

individuals and corporate and government officials.

Among the many sources from which assistance was received the authors wish especially to mention the following:

The Division of Water Resources, California State Department of Public Works, Harold Conkling, Deputy State Engineer, George B. Gleason, Senior Hydraulic Engineer, and John Haley, Administrative Assistant.

United States Bureau of the Census, which prepared and made available certain advance results of the 1935 Federal Census of Agriculture especially for this report.

United States Geological Survey, which supplied, through Fred C. Ebert, Senior Hydraulic Engineer, and K. R. Melin, Assistant Hydraulic Engineer, certain official stream flow and water level measurements in advance of publication.

Division of Western Irrigation Agriculture, Bureau of Plant Industry, United States Department of Agriculture, which through C. S. Scofield, Principal Agriculturist in Charge, and F. M. Eaton, Associate Physiologist, supplied analyses of river and well waters and discussed their qualities.

University of California, which through Prof. Charles F. Shaw, Head of Division of Soil Technology, supplied certain unpublished results of recent soil surveys; and through Dr. B. A. Madson, Head of Division of Agronomy, extended advice regarding certain agricultural problems peculiar to Mojave Valley.

H. E. Drobish, Director of Rural Rehabilitation; Wm. Cook, Director of Agriculture and Subsistence for San Bernardino County Area, and H. S. Frederick, Engineer, Emergency Relief Administration, State of California.

H. D. Wilder, San Bernardino County Farm Advisor.

Walker Jones, Deputy Agricultural Commissioner, San Bernardino County.

Southern Sierras Power Company.

Dr. George P. Clements, Manager of Agricultural Department, Los Angeles Chamber of Commerce.

Federal Land Bank of Berkeley and W. A. Foster, Secretary-Treasurer of Apple Valley National Farm Loan Association.

W. P. Rowe, Consulting Engineer.

J. B. Lippincott, Consulting Engineer.

Leroy A. Palmer, former Mineral Examiner for United States General Land Office.

Dix Van Dyke

Kemper Campbell

FRONTISPIECE

MOJAVE VALLEY AND ADJACENT AREAS

GENERAL FACTORS

Location and Description

Mojave Valley is wholly in San Bernardino County, California, and comprises a regionally important portion of the extensive area known generally as Mojave Desert. Barstow, the largest town in the valley, is about 150 miles north-east of Los Angeles and 80 miles north of San Bernardino. Victorville is next in size to Barstow, and is situated more centrally as regards the agriculturally developed portion of the county, being about 35 miles southwest of Barstow.

The desert region of southern California, including its part of Mojave Desert, is separated from the Coastal region by a rugged, continuous chain of mountains. This chain is divided by more or less pronounced topographic features into several minor ranges, two of the more important of which are the San Gabriel Mountains and the San Bernardino Mountains. These two are, topographically and geographically at least, one range, the line of demarcation being Cajon Canyon. The San Gabriel Mountains lie west of the canyon; the San Bernardino Mountains lie to the east of it.

Mojave River is in the Great Basin and constitutes the chief drainage system of the northern slopes of the San Bernardino Mountains, rising in a section generally opposite the source of Santa Ana River, which rises on the southern slopes of the mountains in San Bernardino County, and flows thence in a southwesterly course through Riverside and Orange counties to the ocean. The mountain headwaters of Mojave River comprise two distinct branches, East Fork, or Deep Creek, and West Fork, which unite at the base of the mountains to form the main river. This junction is known as the Forks. Below it the river, in its course of 90 miles across the desert plain, receives not a surface tributary of consequence. The course of the river is first northward 30 miles, then northeastward 20 miles, and finally eastward 40 miles. The river sinks at Soda Lake at an elevation between 900 to 1,000 feet above sea level.

The river has peculiar characteristics which, combined, almost comprise uniqueness. It receives a small underground replenishment from territory outside its surface drainage and contributes a small underground supply to other territory similarly situated. It practices conservation by storing parts of its flood waters in large absorption areas and yields this stored water later as perennial stream flow. It brings its water to the surface at frequent intervals so spaced that the maximum benefits to man are derived, then husbands its water beneath the reaches of evaporation until the next oasis is reached. While apparently capable of supporting an agricultural area of large extent, the Mojave now serves an acreage of fractional extent, although with no general overdraft on the water stored naturally underground such as has taken place in some of the coastal valleys.

Outside of the towns along the railroads, all the population is located on the irrigated farms and small homesteads in the valley. The

rural population is nearly all American born, but a large Mexican population works on the railroads. Barstow, the largest town in the valley, is an important railroad division point, and Yermo, located on the Union Pacific about 14 miles east of Barstow, is also made up largely of railroad workers. Other points on the railroad consist of Bryman, Helendale, Hodge, and Hinkley in the Middle Mojave Valley. Daggett, Minneola, and Newberry, located on the Santa Fe in the Lower Mojave Valley, are used for water stations; likewise Harvard on the Union Pacific.

None of the valley's towns is incorporated, but the following figures from the 1930 Federal Census show the approximate distribution of the population. The divisions shown are judicial townships. (See Frontispiece.)

Township	Total	Rural - farm
Barstow	2,455	354
Belleville	522	57
Hesperia	391	132
Oro Grande	754	247
Victor	2,173	301
Yermo	400	21
Total	6,695	1,112

Thus, despite the fact that the valley has only two towns of population above 1,000, only one-sixth of its total number of persons live either on the farms or outside the several centers.

Climate

The climate is notably characteristic of that of the Mojave Desert region in that the total annual precipitation is very low, has low humidity, high temperatures in summer, and a wide daily range in temperature. Strong winds occur at certain seasons.

The mean annual precipitation at Barstow (elevation 2105) is 4.10 inches. The maximum annual precipitation has been as much as 10.99 inches and the minimum 0.80 inch. More than 60 percent of the annual precipitation occurs during the months of December, January, February, and March, when plants are dormant. Victorville, at an elevation of 2727 and about 35 miles southwest of Barstow, has a mean annual rainfall of 5.38 inches. Anywhere, however, there may be a wide fluctuation from the mean in single years because of storms striking one place and not another in their passage from the mountains to the south out across the desert. In general, it may be stated that the mean annual rainfall varies from about 6 inches in the upper valley to approximately 3 inches in the extreme northeastern part farther out on the desert.

Barstow has a growing season with an average length of 245 days. The average date of the last killing frost in the spring is March 8, and the average date of the first killing frost in the autumn is November 8.

The latest recorded date of killing frosts in the spring is April 3, and the earliest recorded date of killing frost in the autumn is October 19.

In general, the growing season and the temperatures increase with a decrease in altitude. It may be assumed that the growing season is shorter in the sections having elevations of about 2600 feet than in the portions lying at 1800 feet or lower.

The daily range in temperature is usually large. Nights are usually fairly cool, while days are hot during the summer.

Winds follow down the valley. The prevailing direction at Victorville is from the south; at Barstow and Daggett from the west. During the spring, winds reach a maximum velocity of 25 to 35 miles per hour at Daggett. A large amount of sand is moved by these winds in the dry channel of the Mojave River. Sand dunes are occasionally found associated with riverwash in the river channel. Blowing and moving sand constitutes a real problem in establishing crops on some of the sandier soil types. Windbreaks have aided to some extent in relieving this condition. Tamaracks are grown along the fences and ditches for this purpose.

High temperatures and low humidity produce a high rate of evaporation, which soon disposes of the scanty rainfall. Heavy evaporation and transpiration take place from areas where the water table is close to the surface.

The rainfall is so slight that very little grass springs up following the rains on the desert removed from the river. Crops cannot be grown without irrigation. Rains are so uncertain and small that not even summer fallow practice carries over enough moisture for crops from one year to the next.

The general characteristics of the climate commend it to persons suffering from asthma and similar troubles, and several of the older farms have developed something of a reputation as guest or dude ranches among patrons seeking health or enjoying desert environments.

Table 1 summarizes precipitation and temperature records accumulated by the United States Weather Bureau at Barstow. Available precipitation records for Helendale are summarized in Table 2 and for Victorville in Table 3. Precipitation in the mountain watershed is discussed in the chapter on Water Supply.

Markets and Transportation

The valley is exceptionally well provided with transportation facilities. The tracks of the Santa Fe Railroad are shared with the Union Pacific from San Bernardino to Daggett, whence they continue eastward to Needles; the Union Pacific branches northeastward through Yermo and Harvard on its way to Las Vegas and Salt Lake City. A branch line of the Santa Fe extends from Barstow westward to Hinkley and connects with the San Francisco line at Mojave. Transcontinental paved highways cross the valley, Highway 91 branching at Daggett and the Arrowhead Trail (Highway 66) going through Daggett and Yermo on its way to Las Vegas. Secondary roads are all good.

Bridges cross the Mojave River at Victorville, Daggett, and Barstow, During periods of high water, difficulty may be encountered in fording it elsewhere. In fact, although the river bed is usually dry, it is extremely sandy and not easy to cross in some places.

Table 1. - Normal monthly, seasonal, and annual temperature and precipitation at Barstow, California. (Elevation 2105 feet)[1/]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1904)	Total amount for the wettest year (1918)
	°F	°F	°F	Inches	Inches	Inches
December	45.8	87	12	0.52	T	0.50
January	46.1	82	12	.76	T	.13
February	50.3	86	16	.56	.30	.75
Winter	47.4	87	12	1.84	.30	1.38
March	56.1	94	21	.64	.10	2.18
April	61.7	99	30	.15	.00	T
May	67.5	111	34	.12	.00	.62
Spring	61.8	111	21	.91	.10	2.80
June	77.7	113	40	.13	.00	2.97
July	83.7	114	50	.22	.40	1.28
August	82.4	112	48	.15	T	.06
Summer	81.3	114	40	.50	.40	4.31
September	74.1	111	39	.22	.00	1.48
October	63.8	97	27	.39	.00	.78
November	54.0	90	14	.24	.00	.24
Fall	64.0	111	14	.85	.00	2.50
Year	63.6	114	12	4.10	.80	10.99

1/ Does not include records later than June 30, 1921, when the Barstow station of the United States Weather Bureau was closed.

TABLE 2 . - Monthly, seasonal and average amounts of precipitation, in inches, at Helendale, Calif.

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Season
1904-05	0.00 1/	0.00 1/	0.31	1.30	1.94	2.10	0.38	0.43	0.00	0.00	0.00	0.03	6.49
1905-06	.00	1.78	.00	.75	.76	.81	.69	.34	.00	.00	.48	.00	5.61
1906-07	.00	1.00	2.00	1.34	.67	.60	.00	.00	.00	.00	.00	.00	5.61
1907-08	1.62	.00	.00	1.74	1.22	.11	.10	.00	.00	.00	.43	.32	5.54
1908-09	.42	.00	.19	.57	.03	.05	.00	.00	.00	.06	.00	.00	1.32
1909-10	.00	1.12	1.23	1.18	.00	.30	.00	.00	.00	.00	.00	.00	3.83
1910-11	1.08	.00	.00	.90	.82	.00	.00	.00	.00	.00 1/	.00 1/	1.00 1/	3.80
Means 2/	.44	.56	.53	1.11	.78	.57	.17	.11	.00	.01	.13	.19	4.60

1/ Estimated.

2/ Monthly and seasonal average for 7 years.

TABLE 3. - Monthly, seasonal and average amounts of precipitation, in inches, at Victorville, Calif., (Elevation 2716 feet)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Season
1904-05	0.10	0.00	0.40	1.27	2.12	2.19	0.04	0.58	0.00	0.00	0.24	0.03	6.97
1905-06	.00	2.80	.02	.37	.74	1.13	.35	.21	.00	.32	.00	.05	5.99
1906-07	.00	1.96	2.00	2.13	1.00	1.15	.00	.00	.00	.00	.00	.00	8.24
1907-08	1.85	.12	.10	1.73	1.51	.26	.02	.16	.00	.00	.10	1.40	7.25
1908-09	.89	.00	.20	.52	.49	1.20	.00	.14	.00	.00	.31	.00	3.75
1909-10	.00	.25	2.01	1.37	T	.53	.00	.00	.00	.21	.00	.00	4.37
1910-11	.23	.17	T	.89	1.26	.23	.20	.06	T	T	.00	1.95	5.00
1911-12	.19	.00	.02	.00	.00	3.10	.18	.11	.00	T	.00	.00	3.60
1912-13	.00	.00	.00	.57	.85	.18	.00	T	.02	.55	.12	.00	2.30
1913-14	.05	.96	.16	3.10	2.00	.10	1.04	.12	.09	.09	.00	T	7.71
1914-15	.46	.15	2.23	2.70	1.58	.32	.50	.13	.00	T	.26	.56	8.89
1915-16	.00	.13	1.04	2.33	.40	.17	.37	.11	.00	.00	.30	.16	5.01
1916-17	.29	.00	1.68	1.57	.06	.27	.11	.18	.00	.08	.00	.00	4.24
1917-18	.03	.00	.00	.13	1.88	1.63	.00	.11	.00	.35	.32	.17	4.62
1918-19	1.50	.81	.45	.02	.00	.00	.00	.00	.00	.00 1/	.00 1/	.00 1/	2.78
Means 2/	.37	.49	.68	1.24	.93	.83	.19	.13	.01	.11	.11	.29	5.38

1/ Estimated.
2/ Monthly and seasonal averages for 15 years.

Electric power is available for domestic purposes and irrigation pumping near Barstow and throughout the valley to the west. Schools, churches, and other social institutions are all available.

Alfalfa, dairy products, turkeys, and a few poultry products are the only agricultural commodities marketedto any extent outside the valley. Alfalfa is the chief commodity and is hauled by trucks to the markets on the coast and other points in southern California. Dairymen and rabbit growers in Etiwanda, San Bernardino, Riverside, Pomona, and other nearby towns use considerable Mojave Desert alfalfa hay, which is baled on the farms and sold to the buyers in the bale on the farm. Good Mojave Desert hay usually sells at a premium.

Geology and Topography

The valley area under consideration consists of the recent flood plain of the Mojave River and the alluvial terraces bordering it. Fairly recent and old alluvial fans extend down from the desert mountains which flank the valley at a distance of two to eight miles. These recent alluvial fans have a sloping terrace-like relief that is badly eroded. The recent flood plain deposits of the Mojave River have a width of one-half to one mile. Sand dunes occur in a number of places paralleling the channel of the Mojave River, a well defined belt of dunes stretching across the Lower Mojave Valley from a point about four miles southeast of Yermo, nearly to Newberry Station. (This belt is referred to later as the "Forks-of-the-Road Fault.") Some of the dunes rise 10 to 25 feet above the level of the plain. The eastern edge of this dune belt is rather sharp, while the western edge is more or less irregular. Another dune area is northeast of Newberry Station bordering Troy Dry Lake. These dune areas in the Lower Mojave Valley are no doubt due to a high ground-water level, with mesquites growing up and windblown sand gathering around them. East of the dune belt the water level is generally lower than on the west, and the pumping supply is less dependable.

The following paragraphs, which describe the agriculturally important portion of the area with which this report is directly concerned, are abstracted from State Bulletin No. 47.[1]

Upper Mojave Valley. - "The Upper Mojave Valley (see Plate 4-A in Appendix) is a part of a broad piedmont plain that slopes away from the northern front of the San Gabriel and San Bernardino mountains, along which it abuts for a distance of about 100 miles. Its eastern and western limits are formed respectively by the apices of the cones built by Arrastre Creek (six miles east of the Forks of the Mojave River) and Sheep Creek, (21 miles west of the Forks of the Mojave River). Its southern border is formed by a series of protruding bedrock hills that produce a narrowing of the valley in the vicinity of Victorville and Adelanto. The alluvial fill of the Upper Mojave Valley is apparently truncated on its south by a buried fault, designated here as the Ord Mountain Fault, along the northern toe of Ord Mountain and the front of the hills of Tertiary sandstone which occur north of Horsethief Canyon. Lying between the latter hills of Tertiary sandstone and Ord Mountain are dissected hills of alluvium, bounded on the south by the proposed Forks reservoir site and on the north by the above mentioned fault.

1/ California State Department of Public Works, Division of Water Resources, Bulletin No. 47, "Mojave River Investigation," 1934, by Harold Conkling and George Gleason.

These sediments have been formed by the outwash of the West Fork of the Mojave River and probably do not have great thickness south of the indicated Ord Mountain fault. North of the fault and over the greater part of the Upper Mojave Valley the depth of the water-bearing series has not been clearly determined. The wildcat oil well of the Victor Valley Oil Company, Victor No. 1, located in the SE$\frac{1}{4}$ of Section 20, T 5 N, R 5 W, S.B.B. & M., logged water-bearing sands and gravels from the surface to 730 feet; pink shale, brown sandy shale and hard sand from 730 feet to 1350 feet, excluding five feet of water gravel encountered at 1060 feet; and brown shale, lime and schist from 1355 to 1600 feet, total depth. A water well located in the SE$\frac{1}{4}$ of Section 16, T 5 N, R 4 W, S.B.B. & M., reported water-bearing alluvial fill from the surface to 835 feet and hard granite from 835 to 861 feet, total depth. The wildcat well of the Hesperia Oil and Gas Company, No. 1, located in Section 29, T 4 N, R 4 W, S.B.B. & M., logged sand, gravel and gravelly clay from the surface to 885 feet; lime, talc, clay, hard sand and gravel from 885 feet to 1105 feet; hard sand, sandy shale, brown shale and lime from 1105 to 2941 feet; and limestone formation with streaks of fossil shells from 2941 to 3033 feet, total depth. A water well located in Section 35, T 4 N, R 5 W, S.B.B. & M., and about two miles north of the San Bernardino Mountain-front, encountered the water table at a depth of approximately 750 feet, indicating that the bedrock near the mountain-front is quite deep. It is possible that the material logged largely as hard sand and shale in the Victor Valley Oil Company No. 1 well from 730 to 1350 feet and in the Hesperia Oil and Gas Company No. 1 well from 885 to 2941 feet, may be correlated with the Tertiary sandstone which forms the hills south of Hesperia, and that the rocks penetrated at greater depths are a part of the basement complex. This inference, together with the depth to bedrock in the water well situated in Section 16, T 5 N, R 4 W, S.B.B. & M., and the relatively deep bedrock indicated along the San Bernardino Mountain-front would suggest that the Quaternary water-bearing series has been deposited upon a relatively flat surface of the nonwater-bearing series and that it is approximately 800 feet thick in the central part of the valley and somewhat thicker adjacent to the mountain-front along the upper part of the alluvial cones. At least, the pervious fill is approximately limited to these depths.

"The Mojave River has entrenched itself in a deep channel, extending over the entire length of the upper valley. In the locality known as the Upper Narrows, near Victorville, it has cut a narrow V-shaped channel into the resistant granitic rocks which form a spur to the hills along the eastern boundary of the river. Above the Upper Narrows it has widened its trench in the non-resistant fill material to an average width of about one mile. Recent fill has been deposited in its newly cut channel to a depth of about 50 feet. This latter figure is based upon test holes bored by the U. S. Geological Survey[1/] in the Upper Narrows.

"The material comprising the older Quaternary fill has been considerably altered through weathering and as a result, its specific yield has been greatly reduced. Based on a study of a few well logs and a comparison of

---

1/ U. S. Geological Survey, Water Supply Paper 140, "The Rate of Movement of Underground Waters," 1905, by Charles S. Slichter, p. 56.

the older fill to similar material in the South Coastal Basin, a specific yield of from five to 10 per cent is estimated for this altered material. On a like basis a specific yield of from 15 to 20 per cent is estimated for the recent fill deposited in the channel of the Mojave River.

Middle Mojave Valley. - "The Middle Mojave Valley (see Plate 4-B in Appendix) is a long irregularly shaped area, extending from Victorville to a point near Daggett and is bordered by numerous hills whose steep alluvial aprons blend into a former flood plain of the Mojave River that stands considerably above the present stream channel. In this region the Mojave River is bordered by a recent flood plain, varying in width from a mile to a small fraction of a mile, which lies in the bottom of a trench cut into older deposits of the river. Nearly everywhere the bordering topographic features suggest that the bedrock lies at no great depth, although there are no available logs which give specific information. The regions of shallowest bedrock often manifest themselves by rising water in the channel.

"Near Hodge the narrow valley of the Mojave River emerges downstream into a rather broad plain, possessing two outlets through which both surface and underground drainage occur. One is occupied by a gap approximately two and one-half miles wide located to the north and east of Hinkley, and the other is located in the eastern part of the valley and through which the Mojave River continues on its course to Barstow. There is possibly a third underground outlet to the sub-basin located to the west of Hinkley, but the available water levels show no divergence of the water table in this direction. The water table in Hinkley Valley slopes in a north and easterly direction, a portion of the ground water moving through each of the gaps mentioned. Its movement through the gap to the north and east of Hinkley is greatly restricted by a number of small protruding bedrock hills that crop out in the central portion of the narrows. The underflow through this gap joins the water table of Harper Valley which is a deep structural basin filled with water-bearing debris to a depth of at least 2000 feet. This latter depth is evidenced by the C. C. Hamilton wildcat oil well situated in the northwest corner Section 11, T 10 N, R 5 W, S.B.B. & M., which reported sand, sandy clay, gravel, and conglomerate carrying water to 2000 feet; and lime, shale, hard sandstone, boulders and brown shale to 2187 feet total depth.

"Several bedrock prominences occur in the flood plain of the Mojave River in the Hinkley sub-basin, indicating the general shallow character of the fill material. East of the Hinkley sub-basin the Middle Mojave Valley continues again in a narrow confined valley to a point near Daggett where it has its debouchment upon the broad plain of the Lower Mojave Valley.

Lower Mojave Valley. - "The Lower Mojave Valley (see Plate 4-C in Appendix) is a broad triangular shaped flood plain formed by the Mojave River. By the nature of the movement of its ground water, it may be divided into two sub-basins, one occupying the region to the west of the inferred Forks-of-the-Road Fault which traverses the valley in a northwesterly direction from Newberry, and the other occupying the territory to the east of the fault. Along this common boundary line the underground movement of the water has been greatly restricted; an abrupt drop in the

water table of from 25 to 40 feet occurs in a downstream direction at the fault. Considerable sedimentary clay, which has produced an artesian pressure area, has been deposited for a distance of about one and one-half miles above the barrier, indicating that the Mojave River has probably been impounded from time to time as displacement occurred along the fault. All vestiges of the fault in the flood plain area, such as escarpments, have been either erased by erosion or buried by later debris. A direct effect of the fault is the high water table which has encouraged the growth of much water-loving vegetation, which has in turn given foothold to numerous sand dunes that cover a large part of the area above the barrier.

"The river has entrenched itself into a rather narrow channel which becomes progressively deeper downstream from the upper part of the Lower Mojave Valley. Near Daggett its walls are 15 to 25 feet high, while a short distance below Harvard they rise about 75 feet above the channel. This trenching has resulted from a lowering of the local base level in the eastern end of the valley where the river has cut a rather narrow gorge into resistant bedrock.

"The water table of the Lower Mojave Valley slopes in an easterly direction and more or less follows the general inclination of the plains. Ground water 'spills' over the high bedrock present in the lower part of the Middle Mojave Valley into the deeper fill of the Lower Mojave Valley at a point about two miles west of Daggett where the water table stands at a depth of approximately 40 feet below the river bed. Beyond this point the water table gradually approaches the surface of the more steeply sloping stream channel toward the Forks-of-the-Road Fault, where it abruptly drops to depths of from 25 to 40 feet. From here it again gradually approaches the stream level in a downstream direction as the bedrock becomes shallower.

"The thickness of the water-bearing materials has not been determined over the greater part of the Lower Mojave Valley. According to Thompson,[1] a number of wells located in the upper part of the valley have penetrated nearly 500 feet of water-bearing materials without reaching bedrock. A small remnant of lava rises above the plain about two miles northwest of Newberry. This bedrock protrusion, which is possibly related to the Forks-of-the-Road Fault, suggests an irregular bedrock floor. Bedrock also rises to the surface at the lower end of the valley in the stream cut of the Mojave River.

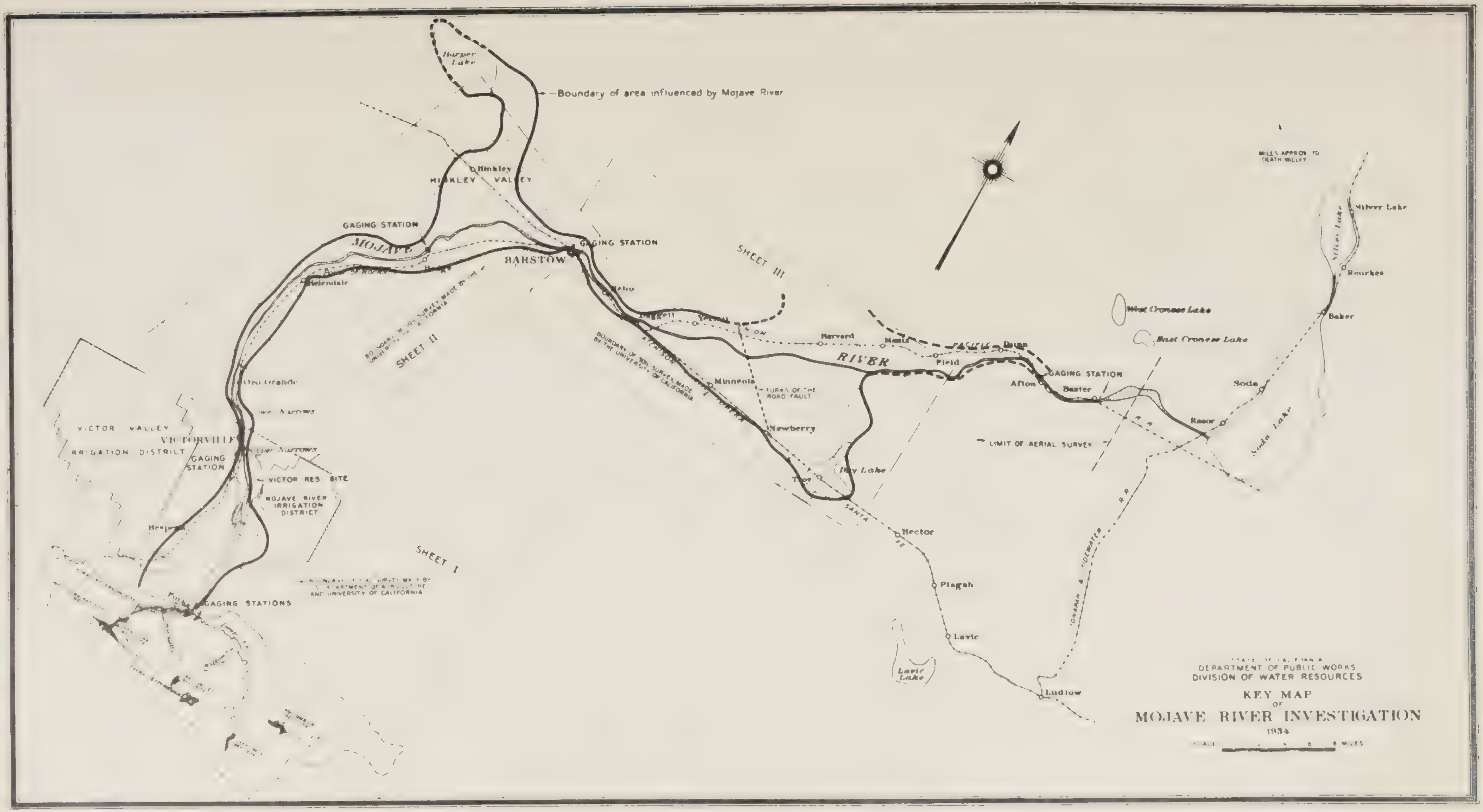
"An analysis of well logs included in the U. S. Geological Survey Water Supply Paper 578 gives for the top 175 feet of material in the upper sub-basin: gravel 40 per cent, sand 24 per cent, and clay 36 per cent. Assuming a specific yield of 18 per cent for the average gravel of this locality (maximum 10 per cent grade size[2] of 32 mm.), 22 per cent for sand, which allows for a relatively large per cent of fine material, and

---

1/ U. S. Geological Survey Water Supply Paper 578, "The Mojave Desert Region," by D. G. Thompson, p. 449, (1929).

2/ California State Division of Water Resources, Bulletin 45, "Geology and Ground Water Storage Capacity of Valley Fill," by Rollin Eckis, Plate XI.

PLATE 1


Boundary of area influenced by Mojave River
Harper Lake
Hinkley
HINKLEY VALLEY
GAGING STATION
MOJAVE
Helendale
BARSTOW
GAGING STATION
SHEET III
SHEET II
SHEET I
Daggett
Harvard
RIVER
Field
Afton
Baxter
GAGING STATION
Minneola
Newberry
Troy
Dry Lake
SANTA FE
Hector
Pisgah
Lavic
Lavic Lake
Ludlow
ATCHISON
PACIFIC
FURKS OF THE ROAD FAULT
BOUNDARY OF SOIL SURVEY MADE BY THE UNIVERSITY OF CALIFORNIA
LIMIT OF AERIAL SURVEY
West Cronese Lake
East Cronese Lake
Rasor
Soda
Soda Lake
Baker
Rourkes
Silver Lake
MILES APPROX TO DEATH VALLEY
Oro Grande
Lower Narrows
VICTORVILLE
GAGING STATION
VICTOR VALLEY IRRIGATION DISTRICT
VICTOR RES SITE
MOJAVE RIVER IRRIGATION DISTRICT
Hesperia
GAGING STATIONS
AND UNIVERSITY OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
KEY MAP
OF
MOJAVE RIVER INVESTIGATION
1934

one per cent for the clayey material, an average specific yield of 13 per cent is indicated. A similar classification of the logs of the lower sub-basin gives: gravel 5 per cent, sand 46 per cent, and clay 49 per cent. Using the same specific yield values as assumed for the individual groups of material for the upper sub-basin, a specific yield of 11 per cent is indicated for the lower area.

"These analyses bring out a striking increase in both the sand and clay content in the lower sub-basin at the expense of the gravel, which decreases from 40 per cent in the upper area to 5 per cent in the lower area. A large part of the clay beds in the lower sub-basin, no doubt, occur in thick confining blankets, and therefore would be only partially drained by a lowering of the water table."

Soil Classification

A cooperative survey of the Victorville area (that portion of the valley above Victorville) was made in 1921 by the United States Department of Agriculture and the University of California.[1/] In 1932 the University of California, College of Agriculture, at the request of the State Division of Water Resources and with funds for field work furnished by the Division, made a survey of the part of the valley influenced by Mojave River from Victorville down river to a line 18 miles east of Daggett. The results of this survey[2/] are not yet published, but the manuscript was made available to the authors of this report. The following paragraphs, based on both reports, are abstracted (slightly amended) from State Bulletin No. 47.

The area covered by the two surveys within the boundary of the survey of the Division of Water Resources is shown on the Appendix figures (Plates 4-A, B and C). The area covered by the survey of 1932 is entirely within the boundary of the Division of Water Resources survey described in Bulletin 47, but the area covered by the survey of 1921 extends outside that boundary. The boundaries of the three surveys are shown on the key map (Plate 1). The University also classified the area encompassed by both surveys as to its suitability for agriculture by the "Storie Index Method of Soil Evaluation."

This soil rating takes into consideration three factors: (A) Rating on basis of character of profile, i.e., mode of formation or accumulation and degree of weathering, (B) rating on basis of surface texture, i.e., loamy, sandy, gravelly, etc., and (C) rating of conditions and characteristics of the soil which modify its suitability for utilization in plant production, i.e., drainage, alkali, erosion, etc. Certain soils with low ratings might successfully produce certain special crops although not well suited to a wide range of crops. Climate and transportation, of course, are not taken into consideration in the rating but exert modifying influences.

1/ U. S. Department of Agriculture, 1921, "Soil Survey of Victorville Area," by A. E. Kocher and Stanley W. Cosby.

2/ Soil Survey of Barstow Area, California, by R. Earl Storie and D. F. Trussell (in press).

Each factor is evaluated on a percentage basis, the ideal condition being 100. The percentage ratings of factors (A), (B), and (C) are then multiplied and the result is the "Soil Index Rating."

For California the soils have been divided into six grades as shown in Table 4.

Table 4. - Agricultural ratings of soil grades in Mojave Valley, California

Grade	Percentage Index	Agricultural Rating
1	80-100	Excellent
2	60- 80	Good
3	40- 60	Fair
4	20- 40	Poor
5	Less than 20	Very poor
6	Less than 10	Non arable

The total area covered by the two surveys is 409,145 acres. The classifications within the boundary of the Division of Water Resources survey are shown in Table 5.

TABLE 5. - Agricultural value of soils in Mojave River Valley, Calif., covered by survey of University of California, 1932 and United States Department of Agriculture cooperating with University of California in 1921 [1]

Area of soils in acres

District	Grade No.	Amount of alkali				Total
		F (free)	S (slight)	M (moderate)	A (strong)	
Mountains to Victorville	1	723	0	0	0	723
Both sides of river	2	39,162	0	0	0	39,162
	3	59,657	0	0	0	59,657
	4	18,861	0	0	0	18,861
	5	13,450	0	0	0	13,450
	6	30,274	0	0	0	30,274
Total		162,127	0	0	0	162,127
Victorville to Barstow	1	301	0	0	0	301
Both sides of river	2	3,139	2,367	0	0	5,506
Victorville to Hodge	3	25,492	687	391	0	26,570
South side of river	4	9,315	1,744	515	0	11,574
Hodge to Barstow	5	21,698	16	0	1,226	22,940
	6	3,033	0	0	0	3,033
Total		62,978	4,814	906	1,226	69,924
Hinkley Valley	1	0	0	0	0	0
North side of river	2	4,475	1,221	116	0	5,812
Hodge to Barstow	3	12,591	3,448	0	0	16,039
	4	193	1,250	2,470	0	3,913
	5	4,504	0	0	0	4,504
	6	0	0	0	0	0
Total		21,763	5,919	2,586	0	30,268
Barstow to East End of Survey	1	0	0	0	0	0
Both sides of river	2	37	1,253	0	0	1,290
Barstow to Daggett	3	20,859	345	424	0	21,628
North side of river	4	2,327	0	212	0	2,539
Daggett to east end	5	5,544	0	0	1,545	7,089
of survey	6	0	0	0	0	0
Total		28,767	1,598	636	1,545	32,546
Daggett to East End of Survey	1	0	0	0	0	0
South side of river	2	0	244	0	0	244
	3	37,515	641	90	0	38,246
	4	3,058	9,151	832	477	13,518
	5	9,485	40	32	6,832	16,389
	6	0	0	0	0	0
Total		50,058	10,076	954	7,309	68,397
GRAND TOTAL		325,693	22,407	5,082	10,080	363,262

1/ Within the boundaries of maps (Plates 4-A, B, and C) in Appendix.

TABLE 6. - Summary of agricultural value of soils in Mojave Basin

Grade No.	Alkali classification				Total	Proportion
	Free	Slight	Moderate	Strong		
	Acres	Acres	Acres	Acres	Acres	Percent
1	1,024	0	0	0	1,924	0.3
2	46,813	5,085	116	0	52,014	14.3
3	156,114	5,121	905	0	162,140	44.7
4	33,754	12,145	4,029	477	50,405	13.8
5	54,681	56	32	9,603	64,372	17.7
6	33,307	0	0	0	33,307	9.2
Total	325,693	22,407	5,082	10,080	363,262	100.0

TABLE 7. - Agricultural value of soils in Mojave River Valley, Calif., covered by soil survey of 1921 but outside of maps in Appendix

Grade No.	Area of soils in acres	Percentage
1	0	0
2	13,021	28.4
3	22,763	49.6
4	5,779	12.6
5	2,855	6.2
6	1,465	3.2
Total	45,883	100.0

As shown by Plates 4-A, B, and C (in Appendix) the different classes of land do not occur in large areas, but are scattered over the entire area mapped.

The names of soils included in each class are shown in Table 8.

TABLE 8. - Names and descriptions of soils in different gradings for agricultural suitability

Grade 1

Hanford very fine sand.

Grade 2

Foster fine sandy loam (slight alkali).
Cajon fine sandy loam (slight alkali).
Rosamond fine sandy loam (slight alkali).
Hesperia loamy fine sand.
Cajon loamy fine sand.
Hesperia loamy sand.
Hesperia coarse sandy loam.
Foster fine sand (slight alkali).
Foster silt loam.
Foster loamy sand (slight alkali).
Adelanto sandy loam, deep phase.

Grade 3

Rosamond silty clay loam (slight alkali).
Daggett loamy sand.
Cajon coarse sand, dark colored phase.
Mojave loam.
Cajon fine sandy loam (moderate alkali content).
Cajon fine sand (slight alkali).
Daggett gravelly sandy loam.
Hesperia sand.
Adelanto loamy sand.
Mojave sandy loam (slight alkali).
Yermo sandy clay loam, dune phase.
Yermo sandy clay loam (slight alkali).
Adelanto sand.
Adelanto sandy loam (slight alkali).

Grade 4

Sunrise sandy loam.
Rosamond silty clay loam (moderate alkali).
Mojave sand.
Yermo sandy clay loam, dune phase (alkali spotted).
Rosamond fine sandy loam (moderate alkali content).
Mojave sandy loam (moderate alkali content).
Yermo sandy clay loam (moderate alkali content).
Cajon coarse sand, loamy phase.
Adelanto sandy loam, heavy phase.
Daggett gravelly sandy loam, stony phase.
Sunrise sand.
Hanford coarse sand.
Cajon coarse sand.
Cajon fine sand, dune phase (slight alkali).
Cajon fine sandy loam (high alkali content).

Table 8, continued

Grade 5

Troy stony sandy loam.
Rosamond fine sandy loam (high alkali content).
Adelanto loamy sand, rolling phase.
Adelanto sandy loam, rolling phase.
Adelanto sand, rolling phase.
Rosámond silty clay loam (high alkali content).
Mojave sand, caliche phase.
Sunrise sandy loam, rolling phase.
Sunrise sandy loam, eroded phase.
Yermo sandy clay loam (high alkali content).
Mojave sandy loam (high alkali content).
Mojave loam, playa phase.
Barstow and Daggett gravelly sandy loam.

Grade 6

Riverwash.
Playa deposits.
Dune sand.
Rough stony land.
Rough broken land.

HISTORY

The agricultural use of water in Mojave Valley has a history extending over 70 years. A few irrigation ditches are believed to have been used before 1870 and several more permanent conduits were built between that year and 1880. The first diversion contemplating extensive development was that of the Hesperia colony involving lands of the Appleton Land & Water Company, but closely following was the Arrowhead development. These two projects have important connection with plans for proposed developments which are more appropriately discussed at another place in this report; hence they are now passed over.

Following them came most of the more ambitious plans for development on the river, such as those at Victorville, Barstow, and Daggett and Yermo, which are described fully in State and Federal Government bulletins.[1] Considerable sums were spent in construction of some of these and even larger amounts for their promotion. Notwithstanding this evidence of confidence, some of these early plans appear, in light of present knowledge,

[1] See especially California State Department of Engineering Bulletin No. 5, "Report on the Utilization of Mojave River for Irrigation in Victor Valley, California," 1918, by W. F. McClure, J. A. Sourwine, and C. E. Tait; California State Department of Public Works, Division of Water Resources Bulletin No. 47; and United States Geological Survey Water Supply Paper 578, "The Mohave Desert Region, California," 1929, by David G. Thompson.

little short of fantastic.[1] Since about 1900 not much effort has been made to promote enterprises as financial investments, and the principal noteworthy schemes have been the creation of two large irrigation districts - Mojave River Irrigation District (1916) and Victor Valley Irrigation District (1917). Both are now dormant; the former made annual assessments for several years in order principally to carry expenses involved in water right litigation and other legal costs, but has not done so in recent years.

Almost nothing substantially important has come of all these ambitious efforts. The 1934 irrigated acreage was, in fact, some 3,300 acres less than the area "on Mojave River and in Victor Valley" reported for (apparently) 1917 by Tait, in Bulletin No. 5. The later figures may properly introduce, however, the mention here of what have really been the most significant phases of the development which has taken place through all the years:

The 1917 compilation showed 3,095 acres as still irrigated from the river; the remainder (6,775 acres) from wells. Latest (1934) Census figures do not make a corresponding segregation, and no other available data bring out the present facts specifically. However, 1930 Census tabulations show only seven ditches as against 22 which appear on an early map, while the number of pumping plants very greatly increased between 1920 and 1930. The fact is that only a few of the old ditch diversions are still active, and the best estimate the authors were able to obtain as to the total area now served by them was around 200 to 300 acres. The remaining area is wholly irrigated from wells, all but a negligible number of which are pumped. Moreover, these pumping plants are almost all operated by individual farmers.

In short, the achievement represented by present development has been that of individual, not community or group effort, notwithstanding the hundreds of thousands of dollars which have been spent by other agencies; and pumping from wells has almost completely displaced the earlier methods of irrigation involving gravity diversion from the river. A gradual increase by individual effort has taken place in the past five years, although the present irrigated area is still less than that reported by Tait for 1917.

FINANCIAL CONDITIONS

Community Obligations

The valley is not heavily burdened with community obligations. The total 1934-35 assessed valuation for the county was \$67,663,023. On a proportional basis represented by the \$562,847 partial valuation shown in Appendix Table A, the valley's share of funded county indebtedness is small. That indebtedness is represented by two bond issues. The first was originally \$1,750,000, dated January 5, 1915, with final maturity 35 years thereafter. On June 30, 1935, \$950,000 of this issue was outstanding.

[1] For instance, the reservoir project above Victorville involved a storage of 250,000 acre-feet based on an estimated annual river discharge of 597,300 acre-feet. Two hundred thousand acres of land was to be irrigated at an average cost, for the entire irrigation system, of \$8.46 an acre.

The second issue had a final 30-year maturity from January 5, 1915, and was for $150,000, of which $100,000 was outstanding June 30, 1935. Both issues pay 5 percent interest.

Aside from two small assessment bond issues against specific property in Barstow, the only other bonds affecting Mojave Valley civil division are those of the following school districts:

School district	Outstanding bonds Dollars
Barstow	500
Hesperia	3,500
Todd	1,500
Victor	20,500
Yermo	2,000

Tax Rates

Valuations established for taxation purposes are discussed elsewhere in this report. Table 9 shows by school districts, the various tax rates, per $100 of assessed valuation, applying to the valley area.

The list of tax delinquencies for San Bernardino County published June 5, 1935, and involving the county taxes levied in 1934 for the fiscal year 1934-35, is voluminous, and the portion of it which applies to Mojave Valley districts is proportionately so. However, most of the delinquencies listed are small, and at least so far as the areas near the river are concerned, their totals do not give the authors the impression that the situation is extraordinary to a serious degree. Facts are not at hand to indicate the extent of unpaid taxes accumulated prior to the year just closed.

AGRICULTURAL AND ECONOMIC CONDITIONS

Analysis of Present Farming

An analysis of Mojave Valley farms as of January 1, 1935, in which the extent, value, and use of the land in farms is shown, is presented in Table 10. This was made available for this report in advance of normal publication date by courtesy of Director W. L. Austin, of the United States Bureau of the Census. The table is based on data collected in the 1935 Federal Census of Agriculture, in which the judicial township (for San Bernardino County) was the only minor civil division recognized. Fortunately, the agriculturally important portion of the valley is closely identified by the six judicial townships listed, and although Lucerne Valley, Adelanto, and other detached localities are represented by the statistics, the cropped and irrigated areas in those localities are so limited as not to invalidate the figures.

It is interesting to note that the total area cropped in 1934 was some 1,500 acres more than the corresponding 1929 area, notwithstanding

TABLE 9. - 1934-35 tax rates per $100 of assessed valuation, by school districts in Mojave Valley

School district	Judicial township	Elementary	Building	High	Junior college	New bond	Total school	Super-visors budget	Co. bonds and interest	Library	Grand total
Apple Valley	Hesperia, Victor	.30	.25	.60	.15	.12	1.42	1.70	.21	.07	3.40
Barstow	Barstow, Belleville	-	-	.75	.15	.43	1.33	1.70	.21	.07	3.31
Big Bear	--	.30	.10	.60	.15	-	1.15	1.70	.21	.07	3.13
Daggett	Belleville	.10	.32	.75	.15	-	1.32	1.70	.21	.07	3.30
Fairview	Belleville	-	-	.75	.15	-	.90	1.70	.21	.07	2.88
Helendale	Oro Grande	.30	-	.75	.15	-	1.20	1.70	.21	.07	3.18
Hesperia	Hesperia	.20	-	.60	.15	.20	1.15	1.70	.21	.07	3.13
Hinkley	Barstow	.30	.34	.75	.15	-	1.54	1.70	.21	.07	3.52
Hodge	Oro Grande, Victor, Barstow	.30	.14	.75	.15	.95	2.29	1.70	.21	.07	4.27
Minneola	Belleville	.30	-	.75	.15	-	1.20	1.70	.21	.07	3.18
Oro Grande	Oro Grande	.04	-	.60	.15	-	.79	1.70	.21	.07	2.77
Todd	Barstow	-	-	.75	.15	.80	1.70	1.70	.21	.07	3.68
Victor	Victor	.55	.60	.60	.15	.46	2.36	1.70	.21	.07	4.34
Yermo	Yermo	.30	.70	.75	.15	.67	2.57	1.70	.21	.07	4.55

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

increases also in the areas of "crop failure" and "idle or fallow." Likewise interesting is the increase in number of farms[1] from 315 to 426. On the other hand, the 1935 area of "all land in farms" is a third smaller than the previously reported figure, and the total 1935 value of farm land and buildings is less than three-fifths the 1930 figure.

Attention is also here directed to the figures for "land available for crops" (17,000 acres), which is in a general way an indication of the opinion of the farmers as to the limit of the development of croppable acreage which can be effected in the now-operated farms.

Crops

Supplementing the statistics of area in Table 10, Table 11 shows crop figures for the "Mojave district"[2] reported for the years 1929 to 1934, inclusive, by the office of the Agricultural Commissioner of San Bernardino County, which serve to picture clearly the kind of farming principally followed. Thus it discloses with sufficient accuracy the range and relative importance of the different crops now raised in Mojave Valley, with one exception which has connection with matters of concern to the alfalfa growers and which is discussed at length in later paragraphs. This exception is grain, which may presently have more than its present significance as a rotation crop. Though not of past importance as revenue producers, the prospectively necessary frequency of alfalfa reseedings and the consequent interruption of alfalfa cropping every fourth year or so may introduce wheat, barley, and corn as rotation crops, into a more prominent position than they have had heretofore.

Of outstanding interest in the table, however, are the predominance shown for alfalfa throughout the record and the increase of that predominance accompanying the decline of fruit (notably apples). Thus in 1929 fruit represented nearly 13 percent of the total crop value, while in 1934 it was little more than 1 percent. The principal obvious explanation of this change is the severe price decline which became precipitate in 1932 when only 39 cents a box was received for apples. This has dragged production down to one-ninth the crop reported in 1929. In fact, whereas 15 or 20 years ago apples and other deciduous fruits were believed to have great promise in Mojave Valley, and although many small family orchards still remain, as commercial crops the various fruits listed in the table do not constitute a demonstrated proof that the valley is a potential fruit producer of importance. The few commercial apple orchards that remain are in a state of neglect which seems to presage their early disappearance from the agricultural picture.

On the other hand, the abrupt decline of apple production was accompanied by a sharp increase in alfalfa. However, apparently at the peak the acreage of producing apple orchards in 1929 was only about 400 to 500

1/ A "farm," for census purposes, is all the land which is farmed by one person, either by his own labor alone or with the assistance of members of his household or hired employees. Enumerators are instructed not to report as a farm any tract of land of less than 3 acres, unless its agricultural products in the census year are valued at $250 or more.

2/ Includes all that part of the county which is north of the mountains.

DEPARTMENT OF COMMERCE
BUREAU OF THE CENSUS
1935 CENSUS OF AGRICULTURE

July 10, 1935

TABLE 10. - Specified items for six minor civil divisions in San Bernardino County, California, 1935

Judicial township	Number of farms, Jan.1, 1935	All land in farms, January 1, 1935, classified according to use in 1934									Irrigated land	Land available for crops	Value of farm land and buildings
		All land in farms	Crop land			Pasture land			Woodland not used for pasture	All other land in farms			
			Crops harvested	Crop failure	Idle or fallow	Plowable	Woodland	All other					
		Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Dollars
Hesperia	63	6,086	1,339	105	760	36	--	977	7	2,862	1,092	2,240	418,900
Victor	68	13,075	1,644	390	4,681	380	830	2,004	260	2,886	1,642	7,095	881,650
Oro Grande	147	10,771	1,737	100	2,070	--	1,202	1,158	--	4,504	1,652	3,907	1,035,550
Barstow	106	13,988	1,833	103	1,090	88	250	3,198	--	7,426	1,812	3,114	860,950
Belleville	29	5,607	307	103	93	--	--	1,312	85	3,707	307	503	151,900
Yermo	13	3,128	28	3	111	--	640	1,061	--	1,285	28	142	76,005
Total	426	52,655	6,888	804	8,805	504	2,922	9,710	352	22,670	6,533	17,001	3,404,955

TABLE 11. - Crop production in Mojave District, San Bernardino County, California, with unit prices received by farmers, 1929-1934
(Prices are stated in dollars)

Crop and price	1929	1930	1931	1932	1933	1934
Apples, boxes	45,000	40,000	35,000	5,000	4,500	4,000
Price per box	1.40	0.65	0.39	0.39	0.60	0.69
Apricots, tons	--	--	16	--	--	--
Cherries, tons	2	2	2	3	1	2
Price per ton	200.00	160.00	200.00	140.00	140.00	189.00
Grapes, tons	--	--	2	40	30	40
Price per ton	--	--	20.00	10.00	19.00	15.45
Peaches, tons	--	425	300	5	--	--
Price per ton	--	20.00	50.00	21.50	--	--
Pears, tons	175	225	175	100	16	50
Price per ton	60.00	50.00	50.00	43.00	33.50	50.00
Potatoes, sacks	--	--	--	500	1,000	--
Price per sack	--	--	--	0.70	1.90	--
Corn, sweet, lugs	--	--	--	250	600	--
Price per lug	--	--	--	0.26½	0.30	--
Corn, ensilage, tons	4,000	2,700	4,200	3,600	450	--
Price per ton	5.00	5.00	4.00	4.50	3.50	--
Alfalfa hay, tons	25,050	37,200	45,500	45,500	36,000	39,000
Price per baled ton	20.00	15.00	12.00	10.75	12.00	13.00
Alfalfa seed, pounds	--	3,000	2,340	--	--	--
Price per pound	--	0.20	0.10	--	--	--
Melons, tons	--	--	--	45	--	--
Price per ton	--	--	--	7.55	--	--

acres,[1] so that the increase in alfalfa acreage was somewhat greater in the period covered by the table. The alfalfa acreage does not, of course, appear in the table, but other records in the office of the County Agricultural Commissioner show 6,000 acres as the 1934 figure for the district. The latter, like the 1935 Census figures, includes Lucerne Valley and other small isolated sections not now under consideration. The agreement between the two compilations is fully as harmonious as should be expected, the excess of 888 acres in the Census figures for crops harvested apparently being about right to account for all other crops than alfalfa.

An acreage of 6,000 and a production of 39,000 tons means $6\frac{1}{2}$ tons of alfalfa an acre. This is so extraordinary an average that the authors are inclined to question it. Exceptionally high yields are admittedly obtained by many farmers in the valley, and the authors talked with several who cut crops of 8, 9, or even 10 tons to the acre from alfalfa in its prime. On the other hand, the valley is not free from the wide-spread puzzling ailments of alfalfa which are necessitating the frequent reseedings mentioned briefly above, and since these operations are preceded by a year or so of yields somewhat smaller than the best, and usually a year in which the field is in grain, as well as being followed by an initial season in new alfalfa, it is likely that no more than 5 tons an acre should be considered as the annual average for the valley.[2]

In brief, the valley's present agriculture centers upon the production of alfalfa. Anticipating no development which is likely to change this condition a great deal, the authors find themselves sharing the concern of the farmers over the future of their best and almost only crop in view of the fact that its afflictions appear to be growing more and more serious, rather than decreasing. Accordingly, they addressed an inquiry to Dr. B. A. Madson, Head of the Division of Agronomy, College of Agriculture, University of California, asking for information as to what progress is being made in scientific studies of alfalfa diseases. Dr. Madson's reply includes the following paragraphs. What he says regarding early cutting is especially applicable to the Mojave Valley farmers, one of whose best markets is represented by the rabbit hutches of sections south of the mountains, which demand a hay of the soft, leafy type he mentions and for which they pay a premium:

> "I have your letter regarding the alfalfa problems of the Mojave Valley and other regions. The short life of stands and the reduction in yields must be attributed to various causes. In the first place, we find that in practically all of the alfalfa-growing sections the original stand of alfalfa will remain productive for much longer periods than will subsequent plantings,

---

[1] Table 10, California State Department of Engineering Bulletin No. 5, shows a total acreage of 796 in apple and pear trees of all ages in (apparently) 1917.

[2] The 1929 average for San Bernardino County reported in the 1930 Federal Census was 4.6 tons, itself an exceptionally excellent average. About two-thirds of the county's crop is raised in the Mojave district. The corresponding 1934 Census average was not available when this footnote was written.

The average yields in the San Bernardino County alfalfa efficiency studies discussed under the heading "Costs of and Returns from Farming" were as follows: 1929, 6.14 tons per acre; 1930, 5.42 tons per acre; 1931, 5.53 tons per acre.

and in most of the older alfalfa sections stands usually do not remain productive for more than four to five years. The cause for this condition is not known although we have been studying it for some time. Part of the trouble is apparently due to changes in our methods of handling alfalfa. The present practice is to cut alfalfa at a much earlier stage of growth than was the case a number of years ago, and our experiments have shown that early cutting weakens the plants, and tends to shorten the life materially. This change in practice has been brought about very largely by the grower's attempt to supply the market demand for a soft leafy hay. However, this is not the sole cause of the trouble; there appear to be other reasons why alfalfa on land which has previously grown the crop will be relatively short-lived, and as I stated before, the cause for this condition has not been determined.

"During the past few years, also, the alfalfa wilt, a bacterial disease, has become rather prevalent in the state. In regions where the infestation is heavy, the stands usually do not last more than three to four years. Since the disease is bacterial and the organisms live over in the soil, or are carried over on volunteer plants, the only remedy for the trouble will be development of varieties resistant to the disease. We are making some progress along this line, but it will be some time before even moderately resistant varieties will be available. Another disease somewhat similar in its effect on alfalfa is the dwarf. This is particularly prevalent in the southern part of the state. Dr. Weimer of the Division of Forage Crops and Diseases has been studying this disease for the past three or four years but has as yet not been able to determine definitely whether it is due to a parasitic organization or not. His investigations during the last year or two, however, indicate that it may be a virus disease and insect-borne. Unfortunately, these investigations are being discontinued as Dr. Weimer is being transferred to other work in the East. However, none of the numerous varieties which he has tested out show any resistance to this disease. Like the bacterial wilt, where dwarf is prevalent the stands usually remain productive for only a few years.

"For the present, therefore, I do not see any liklihood of the farmers being able to maintain good producing stands for more than four or five years. In the older alfalfa-growing sections, the farmers have adapted themselves to this situation and are developing rotations in which alfalfa occupies the land for only short periods. I realize that in the Mojave Valley, where the farmers are at present so dependent on alfalfa, this is not a very satisfactory solution of their problem, but unfortunately we have little to offer at the present time. One expedient that has been used with some success to maintain the stands is to renovate the fields rather heavily in the early spring before the alfalfa stands repeat growth, and at the same time seed broadcast about 15 to 20 pounds of seed. The growth of the older plants should then be kept cut back until about the first to the middle of April in order to give the new seedlings a chance to become established. By doing this the farmer will lose

his first cutting but the subsequent cuttings will usually be very good. In the few cases I know of, particularly in Arizona, good stands have been maintained for many years by this practice."

Properly to be associated with the production of alfalfa is the limited dairy industry of the valley, and, to an even smaller extent, the raising of poultry. Should grain begin shortly to occupy, as expected, somewhat greater importance through rotation with alfalfa, the poultry industry might perhaps show considerable growth, as the climate is favorable and such experience as has already been accumulated, though limited, is not discouraging to an expansion if grain feed, now mostly imported, can be obtained in quantity locally at lowered cost. Such eggs as are produced commercially find markets largely in the valley, but meat fowls, especially turkeys, are sent to San Bernardino, Los Angeles, and other metropolitan dealers.

The small commercial dairies, of which there are perhaps half a dozen, find best outlets for their products in the valley, the not-distant mining towns (such as Randsberg and Johannesberg), and even as far eastward as Las Vegas, but little, if any, in San Bernardino or elsewhere south of the mountains. Promotion of large irrigation projects in the valley from time to time has had in contemplation a substantial expansion of dairying in expectation that milk and milk products would find a ready market in Los Angeles. The proposed El Mojave project, to be described briefly at a later place in this report, was originally promoted on this basis, and as now revived and revised plans for it still have this expectancy as their principal basis, emphasis being placed upon conditions described by Dr. George P. Clements, Manager of the Agricultural Department of the Los Angeles Chamber of Commerce in 1930, as follows. (Recent plans for the project contemplated an acreage much larger than that in mind when Dr. Clements' letter was written):

"In answer to yours and Mr. Merrill's request that I give you a clearcut statement concerning the Helendale project as I see it, I am pleased to state as follows:

"My understanding is that this project comprises some 4,375 acres, plus the riparian rights of 1,100 acres of water-bearing land contiguous to the south of the original 4,375 acres, these water-bearing lands consisting of a continuous strip of varying width over five miles in length so situated as to virtually control and insure an economic and satisfactory water supply for the Helendale Ranch properties.

"I am familiar with this district and the lands in question, and I am satisfied both as to the character of the land and the sufficiency of the water supply in offering a satisfactory agricultural project, my understanding being that the object of the Helendale proposition is the development en masse of this property and not the undertaking of an agricultural subdivision.

"In my estimation this property is admirably suited to the economic production of agricultural crops, particularly that of alfalfa and temperate region crops necessary to a complete animal husbandry, which industry must be considered at the present time one of the few if not the only satisfactory offering to agricultural expansion in the state of California. My opinion is founded on the following known facts:

"While the population of California has increased 64 per cent in the last ten years, and has become a consuming market of fifth importance in the United States (for Los Angeles City), the meat industry has not kept step. We are still bringing from out-of-state 80 to 90 per cent of our pork, 50 per cent of our mutton and 60 per cent of our beef supply. These properties are strategically placed in meeting this acknowledged market.

"The dairy industry, while at the present moment facing an over-supply, cannot be considered as resting upon an economic basis since this supply is at the present time mainly offered through industrial dairy plants which in the face of civic expansion must sooner or later be forced to truly agricultural districts such as the San Joaquin Valley, the Imperial, Palo Verde and Antelope Valleys and the Mojave River district and Southwestern Arizona. The Helendale properties are conveniently situated to meet this demand.

"State laws regulating bovine tuberculosis have caused a considerable embarrassment in the industrial dairy circles and in the replenishment of herds with tubercular-free animals. A new industry therefore has been established throughout the Pacific Southwest - that of producing tubercular-free dairy stock for the immediate supply of the industrial dairies. The Helendale project is conveniently situated to enter into such an industry.

"All of these energies must find their premises in alfalfa production.

"I realize that no agricultural venture under the present deplorable conditions of the nation's agriculture can anticipate major profits. With land and water at reasonable values, such as the Helendale project offers, such agricultural energies offer possibilities of a stable investment with satisfactory earnings, always provided, of course, that they are economically administered."

Dr. Clements, in a conversation with the authors of this report, reiterated the essence of his 1930 opinion regarding the unsatisfactory conditions affecting the milk supply of Los Angeles and the desirability of forcing production back to "truly agricultural districts," but saw no present or early possibility that a new outside supply of large volume could find profitable outlet in Los Angeles because of the control now exercised by the dairies supplying the city. In this opinion he was supported by the dairymen of the valley, who apparently make no effort to find a market across the mountains.

County Farm Advisor Wilder considers that the only opportunity for a successful large-scale dairy development in the valley can come to a close-knit cooperative organization such as does not now exist, which can utilize modern refrigerated transportation in overcoming the valley's relative isolation and handle only milk and such dairy products as the soft cheeses. No authority interviewed gave much consideration to the possibilities of other cheeses and butter.

Dr. Clements' other suggestion regarding the possibilities of a large-scale feeding industry appears to the authors to have logical support in the heavy alfalfa production which now finds distant markets, in the excellent transportation circumstances (especially the convergence of the transcontinental railroads), in the adjacent grazing range (which is, however, of limited availability and productiveness), and in the climate. At first thought it appears strange that such an industry did not long ago take root in the valley.

The authors believe the secret of its non-existence lies in the unwillingness of the farmers to abandon their one-crop specialty. In Mojave Valley, as in other sections where crop-specialization is practiced, an abandonment of the established routine even where profits are promised, is difficult to bring about. The relative simplicity of the alfalfa routine, the ready disposal of the hay for cash, and the freedom from arduous work which follows sale of the season's final cutting, all constitute a type of farming so generally advantageous when compared, for instance, with dairying or even feeding, as not to be surrendered except reluctantly and under some compulsion. Hence, the authors do not expect the valley's hay industry to be dislodged from its dominant position by the present farmers unless downright catastrophe descends upon it. While this is not to say, by any means, that no profitable possibilities whatever lie in dairying, in feeding, or in limited truck growing, it nevertheless appears to the authors that alfalfa hay will continue to be the principal crop of the valley for many years to come.

A most unusually close agreement appears in the statistics regarding the area irrigated in Mojave Valley in 1929. Thus Conkling reports,[1/] "a total area of 6,019 acres irrigated scattered through the valley but mainly in the upper end." The Federal Irrigation Census of 1930 showed for Mojave River drainage basin an irrigated area of 6,118 acres. While the latter figure perhaps involved scattered areas not included in the Conkling figure, the deduction of them would probably serve to increase, rather than diminish, the harmony between the totals as quoted. Anyhow, the agreement is so close as to inspire confidence in other Mojave drainage basin statistics reported by the Census. Table 12 is accordingly shown to describe statistically the irrigation works as they existed in the spring of 1930, as well as the area served and servable and the investment represented. Also shown in the table are comparable figures from the 1920 Irrigation Census.

1/ State Bulletin No. 47.

TABLE 12. - Areas irrigated and susceptible of irrigation, investment in irrigation works, and description of works, 1930 and 1920

Item	1930	1920
Area irrigated ....acres	6,118 1/	4,608 2/
Area enterprises were capable of supplying with water ......acres	8,627	6,510
Investment in enterprises ....dollars	1,192,329	616,769
Irrigation works		
Dams, diversion ....number	7	2
Storage ....number	7	--
Main canals, capacity ..second-feet	143	189
Length ....miles	29	23
Reservoirs ....number	75	18
Capacity ....acre-feet	179	27
Pipe lines, length ....miles	107	29
Flowing wells ....number	17	31
Capacity ....g.p.m.	7,664	4,874
Pumped wells ....number	240	88
Capacity ....g.p.m.	133,557	45,477
Pumping plants ....number	231	86
Engine or motor capacity ....H.P.	3,203	2,145
Pumps ....number	233	86
Pump capacity ....g.p.m.	126,776	45,960
Average lift 3/........... feet	44	80

1/ 1929.

2/ 1919.

3/ Static lift, or average vertical distance between the level of the water in the source of supply when the pump is running and the point to which the water is lifted. Friction and velocity heads are not taken into account.

The foregoing table, with some qualifications, approximately describes the present irrigation equipment of the valley. Most of the flowing wells are now either out of commission entirely or render insignificant irrigation service. Some of the pumping plants have likewise disappeared. The Southern Sierras Power Company is able now to account for 200 plants, 175 of which are operated by electric motors and 25 by internal combustion engines. The Census figure (231) included a number of windmills pumping for small plots,[1] and some of these are still operating, although probably neither are there now nor were there in 1920 as many as 31. This difference therefore apparently represents abandonments of isolated and uneconomical plants, mainly on the higher bench areas where lifts are extreme, and to this extent is significant of the history of the last few years of hard times, notwithstanding the fact that, in total, increases in number of farms and irrigated acreage have taken place. The much-reduced average lift shown for 1930 as compared with 1920 is similarly significant of the important change discussed elsewhere in the matter of orchard abandonments in that period. Most of the commercial apple orchards were irrigated by pumping through lifts so high that when the economic depression began to be felt most severely the cost of pumping could not be supported. The dropping out of the figures representing these lifts and the concentration of development in the areas where lifts were much lower is the explanation, therefore, of the favorable change disclosed by the comparison. Forty-four feet inclusive of drawdown, as reported by the 1930 Census, is considered a fair indication of the present average lift, most of the pumps still being of the centrifugal type, in pits.

Despite the favorable factor of present low-lift pumping, the irrigation systems represent somewhat heavy outlays, averaging on the basis of the 1930 Census figure more than $5,000 each. This is largely by reason of the small reservoirs and concrete underground pipe distributaries which are even more typical of the irrigation layouts than the statistics indicate. As it is, the investment in the pumping plants and their adjuncts constituted about one-fifth of the total 1930 Census value of the farms. If charged to the 1929 irrigated acreage, this investment represents $195 per acre; if charged to the area "enterprises were capable of supplying with water in 1930," the average was approximately $139 per acre.

Types of Farms

Beyond the obvious predominance of the hay farms, no facts are at hand to show a distribution by type of farm as of the present. However, this predominance justifies some assumptions in an examination of the 1930 Census figures for San Bernardino County which lead to interesting conclusions.

Thus it seems apparent that the hay farms were classified in the Census tabulations as "crop-specialty" farms, and since 382 farms of this classification were reported for the county and there were 315 farms in all in the six judicial townships along the river, the "type of farm" tabulations for the county group should represent fairly closely the cir-

---

1/ The Census included all "enterprises" however small which supplied water for irrigation.

cumstances of the valley farms.[1]

These figures disclose the general facts regarding the equipment of the valley farms. The 1930 Census showed a value of approximately $1300 per farm for dwellings, about twice that value for all buildings, and about $950 for implements and machinery. The "type of farm" tabulations showed (for the county) the following figures regarding the livestock population:

	Farms reporting	Number of animals
Horses and mules	268	1,037
Cows and heifers	123	288
Beef cattle	5	79
Other cattle	72	431
Sows and gilts	11	25
Other hogs	17	138

The effect of these figures is that the average Mojave farmer dwelling had a 1930 value very close to that of the average California farm home, a value of all farm buildings a little higher than the State average, and a value of implements and machinery also somewhat higher than the general average. However, it is in point here to note that the equipment of these farms includes few tractors, the machinery being mainly that used in the production of hay, including many baling machines.

On the other hand, while the average number of horses and mules per farm is notably higher than the State average, as would be expected in the absence of mechanical power, the number of other animals is smaller per farm. Relatively few farm gardens were noted by the authors, and the whole general impression gathered from visiting the farms is that a concentration upon the business of raising hay excludes a general interest in other common farm activities.

This is not to imply a poor type of farmer. On the contrary, the farmers appear to be of an exceptionally high type, most of them doing much of their own work and disclosing an alert interest in essential matters affecting their farm business. The 1930 Census showed the following additional "type of farm" figures of interest in this connection, having to do with specified farm expenditures in 1929:

	Farms reporting	Total expenditures
Feed	226	$ 56,541
Fertilizer	79	27,630
Labor	279	342,875

In the above tabulation the fertilizer item is notable in view of the general deficiency of organic matter of the valley soils. Not much fertilizing is done. The several small dairies send most of their manure to the citrus orchards south of the mountains, where it has a ready sale.

[1] This assumption would not be changed materially by the subtraction of the few valley ranches presumably classified as "fruit," "dairy," or "poultry" farms.

Sizes of Farms

San Bernardino County "crop specialty" farms reported in the 1930 Census fell into the following size groups:

Under 20 acres	74
20 to 49 acres	147
50 to 99 acres	70
100 to 174 acres	47
175 to 259 acres	20
260 to 499 acres	13
500 to 999 acres	6
1000 acres and over	5

From the foregoing it is believed correct to assume that more than three-fourths of the farms are less than 100 acres in area, and that nearly nine-tenths of them are smaller than 175 acres. As a matter of fact, even these sizes are not particularly significant, as the average area of crop land (harvested, failure, and fallow) reported in both 1930 and 1935 Agricultural Censuses was 39 acres, and the 1935 average representing harvested and failed crops alone was only 18 acres. The figures merely bring out the point which is obvious to a casual visitor, that many of the farms include considerable areas of desert land some of which is susceptible of improvement, some not, at least economically. The farmers have followed the sensible course of reclaiming first the best part of their homesteads or desert filings, leaving the improvement of the remaining portions for favorable opportunity in those cases where soil quality promises eventual profits from the effort. (See also Table 10.)

In this connection it may be said that various estimates received from farmers who had done or hired such work were more or less universally to the effect that the average cost of preparing Mojave desert land for water, including seeding for alfalfa, ranges around \$50 to \$60 an acre, in some cases being substantially less but in others much more than either figure.

Farm Values and Indebtedness

As already mentioned briefly in the discussion of Table 10, farm values in Mojave Valley have declined severely since 1930, the figures for the current year showing an average per acre of \$65 (for land and buildings) on the basis of all land in farms, as compared with the 1930 average of \$74. Possibly more significant are the averages based on (1) crop land harvested, (2) crop land harvested plus crop failure land, and (3) crop land harvested plus crop failure land plus idle or fallow crop land (and assuming no value whatever for the much larger acreage not in these improved classifications). The 1935 average based on "land available for crops" is \$200. These averages are summarized on the following page:

	Value per acre 1935	1930
	Dollars	Dollars
Crop land harvested	494	1,132
Crop land harvested, plus crop failure land	443	1,016
Crop land harvested, plus crop failure land, plus idle or fallow land	206	492
Land available for crops	200	1/
All land in farms	65	74

Even more significant in the present study are the corresponding comparisons of average values for the different judicial townships. These are summarized in Table 13.

Illustrative of the drastic change in values represented by those now current as contrasted with those reported in the 1930 Census is the taxation basis used by the County Assessor. Assessed valuation now is 31.9 percent of the supposed actual value, and in itself is a reduction of 20 percent from the 1933 ratio. Mojave Valley alfalfa land is now valued for assessment at $25 to $30 an acre, the values used three or four years ago being approximately double these figures. In other words, actual values of alfalfa land are now assumed to range from around $80 to $100 an acre, as compared with, say, $150 to $200 when the 1930 Census was taken.

Improvements and pumping plants are assessed separately from the land, valuations of the latter ranging around $200. Earth reservoirs are not assessed, but concrete reservoirs are, at values also approximating $200.

Deciduous fruit trees are assessed in accordance with the judgment of the assessor, fixed classification values not being used as is done in the citrus-growing sections elsewhere in the county. Livestock and poultry are valued as follows: Family cows, mixed and registered, $15 to $100 per head; bulls, $25 to $300; calves, $3; heifers, $10 to $20; range cattle, $8 to $12; baby beef, 2 cents per pound; work horses, $10 to $40; blooded horses, $50 to $200; work mules, $10 to $40; sheep, $1.50 to $2; bucks, $4; hogs, 2 cents per pound; light hens, $15 per 100; heavy hens, $20 per 100; turkeys, $50 per 100.

Another indication of existing values in the territory with which this discussion is specifically concerned is provided by the 1934 county assessments segregated so as in total to approximate the valley section inclosed in the line bounding the river's influence drawn by Conkling 2/ and shown in this report as Plate 1. The total assessed valuation reported was $562,847, which on the basis of the 31.9 ratio, would indicate an actual value of approximately $1,765,000.

1/ Not reported.
2/ State Bulletin No. 47.

TABLE 13. - Comparative farm values in Mojave Valley, by judicial townships, 1935 and 1930, based on total values of land and buildings

Judicial township	Value per acre, based on acreage of -										Value per farm	
	Crop land harvested		Crop land harvested plus crop failure land		Crop land harvested plus crop failure land plus idle or fallow crop land		Land available for crops		All land in farms			
	1935	1930	1935	1930	1935	1930	1935	1930	1935	1930	1935	1930
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Hesperia	312	1,896	290	1,343	190	561	187	1/	69	53	6,649	35,387
Victor	536	1,039	434	987	131	275	124	1/	67	83	12,955	24,880
Oro Grande	596	1,240	564	1,155	265	412	265	1/	96	94	7,045	15,943
Barstow	470	682	445	638	285	332	276	1/	62	75	8,122	10,446
Belleville	495	1,401	370	1,316	302	331	302	1/	27	77	5,238	18,750
Yermo	2,714	930	2,452	930	535	930	535	1/	24	186	5,847	16,000

1/ Not reported.

The acreage involved in this valuation does not appear in the tabulation (see Appendix), but obviously, while excluding a good deal of the unimproved land represented by the Census figures, it includes some areas (such as town lots, industrial sites, etc.), which (not being in farms) were not involved in the Census canvasses. Moreover, they do not include valuations of buildings or improvements such as pumping plants and reservoirs. They are, in short, representative of land alone.[1]

Still further indicative of average real estate values in the valley are the bases used by appraisers of the Federal Land Bank, as set out in Table 14. In considering these it should be kept in mind that they contemplate supposed normal, rather than the present depressed, conditions. The figures are for values allowed by various appraisers dating back to the early loans. During this period the Bank's standard of valuation has changed to some extent as influenced by boom and depression, but it is not believed that the variation has been such as to throw out of line the values as shown in the table, except that at present enhancement for tree crops, for instance, would be considerably less than indicated in item 6 under Oro Grande area. The enhancement which would be allowed would depend on the condition of the orchard and the proven adaptability of the crop.

The difference in value between maximum and minimum as set up in the table has been due principally to difference in soil and other physical factors rather than the variation in standards of valuation during the period in which the Bank has been loaning in this area.

No statistics are at hand to indicate the extent of mortgage indebtedness. If it be assumed that 1930 Census ratios[2] for San Bernardino County apply to Mojave Valley, 58.3 percent of the farms are mortgaged for 28.5 percent[3] of their value, and pay the relatively high average interest rate of 7.18 percent per annum.[4] Mortgage figures from the 1935 Census were not available when this report was completed. However, it is probable that some considerable change has taken place since 1930 by reason of the recent activities of the Federal Land Bank and the Land Bank Commissioner, which have had at least the one important effect of reducing the interest

---

1/ In comparing this substantially lower total with the Census values, the following explanation from the 1930 Census report, which presumably has application to the 1935 figures also, is in point: "The farmer was asked to .... give the current market value -- that is, the amount for which the farm would sell under normal conditions, not at forced sale." They are therefore the farmers' own valuations and not those of the Census enumerators or other officials. The tax appraiser's valuations, on the other hand, are perhaps reflective of an even lower ratio to true values than the 31.9 proportion supposed to apply, indicating an inclination on the part of the county officials to improve the economic position of the Mojave Valley farmers by lightening their tax burden so far as possible.

2/ The ratio quoted is that applying to all farms operated by owners.
3/ Based on reported indebtedness of farms operated by full owners.
4/ Based on reported indebtedness of farms operated by full owners owning no other farm land.

TABLE 14. - Unit values used by appraisers of the Federal Land Bank of Berkeley in areas along Mojave River

Area	Unit value per acre		
	Maximum	Minimum	Average
	Dollars	Dollars	Dollars
Hinkley Valley T.10 N., R. 3W.			
Alfalfa	200	125	175
Grain land (adaptable for alfalfa rotation)	150	100	130
Leveled land - with water supply - (alfalfa land)	100	100	100
Land not leveled - vacant - water supply available	50	25	28.50
Pasture on river bottom lands	25	25	25
Farmsteads	150	100	140
(All irrigation from pumped ground water.)			
Oro Grande T. 6 N., R. 4 W.			
Alfalfa	200	140	150
Grain and grain hay (alfalfa rotation)	185	125	145
Leveled - vacant - irrigable and water available	75	75	75
Vacant - not leveled - water supply	100	25	36
Irrigated and sub-irrigated pasture	50	10	36
Fruit - apples and pears	300	200	225
Farmstead	150	150	150
Non-irrigated range	2	2	2
(Major part of irrigation by gravity flow from Mojave River.)			
Apple Valley Ts. 4 and 5 N., Rs. 3 and 4 W.			
Alfalfa	200	100	140
Grain and grain hay (alfalfa rotation)	100	75	88.50
Leveled - water supply - alfalfa land	125	70	85
Vacant - not leveled - water supply available	75	15	52.50
Farmstead	150	100	110
Pasture - meadow	50	40	48
River bottom pasture	15	10	11.75
Dry range pasture	2	2	2
(Irrigation from pumped ground water with the exception of 260 acres irrigated from artesian wells.)			

rate. At present there are 29 Land Bank loans averaging about $3,850 each, and 39 commissioner loans averaging $2,782, the two groups totaling $219,200. According to the secretary of the local association, almost no delinquency has characterized the Bank's history in the area, but the number of commissioner loans would indicate that considerable refunding of a distress nature has been undertaken since 1930. It should be observed also that here, as elsewhere, the Bank's appraisals take cautious account of water supply conditions, and various areas (as for instance, much of that east of Barstow) are in effect restricted.

Farm Tenure and Rentals

An exceptionally high degree of ownership by farm operators characterizes the valley. This was apparent to the authors early in their field investigation, and was later verified by examination of the 1930 Census statistics. Thus the "crop specialty" group already referred to was divided in the Census segregations as follows:

	Number
Full owners	228
Part owners	63
Managers	24
Tenants, cash	24
other	43

Corresponding figures from the 1935 Census were not available when this paragraph was written; but if they are in line with the trend of recent years, they should show some increase in tenantry but not enough to change the general significance of the 1930 figures.

Costs of and Returns from Farming

The authors questioned many of the farmers about profits or losses from their business, especially as regarded alfalfa production. These conversations were directed mainly at a verification of such studies of the subject as had been made by other agencies.

The Agricultural Extension Service of the University of California, cooperating with the alfalfa growers of the San Bernardino County Farm Bureau, made such studies in 1929, 1930, and 1931, but has not continued them since. In 1929 only four farms were represented; in 1930 there were six, and in 1931, nine. In 1929 the average net profit per acre above cash costs was $24.32, and above all costs, $82.98; the net profit per ton was $3.96. Average total return per ton was $23.04.

In 1930 the average net profit per acre above cash costs was $31.85, but when all costs were considered the loss was $2.72. On the latter basis, the net loss per ton was 49 cents, but the return above cash costs only was $5.87. Total return per ton averaged $16.25.

In 1931 the average net profit per acre above cash costs was $31.98, but the loss, considering all costs, was $11.33. On the latter basis the net loss per ton was $2.04, but the return above cash costs only was $3.74 per ton. Total return per ton was $11.95.

The analysis of the 1931 operations was the most complete of the 3-year series. For this reason, and because 1931 is the year nearest to the present time, its details are summarized below. During this year, the records were kept by six growers of the Hinkley Valley, Helendale, and Lucerne Valley in the Mojave district, and by one grower in the Chino district. One grower kept separate records on three fields of different ages, so that nine records in all were obtained:

Number of records	9
Total acres	190
Average age of stand .... years	4
Yield per acre .... tons	5.53
Returns per acre ....dollars	66.08
Total cost per acre ....dollars	77.41
Net loss per acre ....dollars	11.33
Cash and labor cost per acre ....dollars	45.43
Returns per acre above cash costs ...dollars	31.98
Returns per ton ....dollars	11.95
Total cost per ton ....dollars	13.99
Net loss per ton ....dollars	2.04
Cash costs per ton ....dollars	8.21
Returns per ton above cash costs ....dollars	3.74

In the above summary, cash costs include all costs except interest and depreciation on investment. Depreciation on alfalfa stand, depreciation on improvements, and depreciation on equipment together were calculated at $18.80 per acre; interest on alfalfa stand, improvements, equipment, and land investment, totaled $13.18. The two totals combined, therefore, comprised 41 percent of the average total cost of production.

Although this cost is not an actual annual cash outlay entirely (interest on indebtedness would be cash, of course), it must be considered over a period of years since replacements and new plantings have to be made and capital investments adjusted periodically. So far as the present conditions and those of the recent past are concerned, it is important to note that the item of interest on investment in land is only $6, or 6 percent on $100 -- perhaps too low, except as reflecting recent Federal Bank refunding, even when the severe decline of values is taken into account. Moreover, the recently increased frequency of reseeding described in a previous section of this report is presumed to mean a higher charge for depreciation of stand than that shown. In short, although the 1934 return to Mojave Valley farmers was $13 per ton (see Table 11), or $1 more than the 1931 price, alfalfa can not yet be considered to return much more than its cost of production when interest and depreciation charges are taken into account. However,

those farmers who have full or substantial equities in their investments are able to continue their operations in relative comfort. All have the advantage, important now and in recent years, of having a product that is readily marketed for cash.

Results of cost and return studies for crops other than alfalfa, having close application to Mojave Valley, are not available to show how the farmers have fared who have tried them out. However, the discussion accompanying Table 11 and the figures in the table which trace the course of prices, are again in point. The fact that alfalfa is the only major crop which has survived throughout the recent years of depression is of principal significance.

All Mojave Valley farmers have benefitted from the reductions of general taxes which have been effected in the last three or four years. However, although this relief has been important, it has been chiefly so by reason of representing a cash cost. The item of "county taxes" averaged only $1.91 per acre in the 1931 cost study, representing 37 percent of the cash overhead but only 35 cents a ton of alfalfa.

In general, there are three different kinds of water rights existing under the law of California: (1) Each acre bordering a stream has a riparian right; that is, it has a right to that portion of the stream flow which it can use beneficially. (2) Each acre overlying an underground basin has a right to use the water, and its owner can insist that no development shall interfere with the supply to the underground basin. (3) The appropriator of water has the third kind of right.

The investigation by the State Division of Water Resources which produced Bulletin 47, disclosed that there is something more than 200,000 acres in Mojave River basin which might be expected to claim one kind of right or another, but the rights involved are mostly those to the use of underground water supplied mainly by Mojave River.

The following sentences from State Bulletin 5, although written nearly 20 years ago, are of significance today. They apply to the portion of the valley south of the north line of Township 7 (south, that is, of Helendale); hence if extended to the remainder of the valley area, the acreage estimates would be somewhat increased:

> The first irrigation ditches on Mojave River were constructed in the early seventies below and near the Lower Narrows. In a few years others were constructed on the West Fork and near the Upper Narrows. It appears that the early irrigators relied mainly on the use of the water to establish their priorities and for some of the ditches did not accompany their appropriations with the formality of filing until after the ditches had been used, while for other ditches they never filed. On the other hand, as with most streams of the arid country, many claims have been recorded which did not materialize by the construction of ditches and use of water. It is estimated from a review of the county water records that several hundred such filings have been made on the Mojave. ....
>
> Under an act of the legislature of 1864 and applying to San Bernardino County only, the county maintained a board of water commissioners for a number of years to administer the waters of the streams, an institution fashioned after that of the early Mormon communities in Utah. The commissioners were to "locate" ditches and to apportion the water in them annually. They annually selected a water master for each ditch to make the apportionment and the reports of the water masters to the board as a matter of record. The main activities of the commissioners related to the more populous settlements on the Santa Ana River and tributaries, but in 1879, acting on petition of residents, they gave attention to irrigation on Mojave River. On January 15th of that year they met on the banks of the river and located six ditches near the Lower Narrows, assigning to them names and numbers and allotting to them amounts ....

The Hesperia Ditch, now owned by the Appleton Land, Water and Power Company, is the only one diverting water away from the lands in the immediate river bottom.

The early settlers took advantage of the locations where the surface flow of the river is constant and the later appropriators had to depend mainly on flood waters ....

No complete adjudication of rights on Mojave River has been made and the few priorities and decreed amounts are fixed only as regards certain other ditches or as regards certain users under other ditches involved in the litigation.........

Owing to uncertain legal definition of riparian land it has not been considered advisable to undertake any exact determination of the extent of such lands. The estimate of the area here given is based on the assumption that the riparian land is limited to the smallest subdivisions that have existed at any time touching the high-water banks of the river and its tributaries and lying within the drainage.

Excepting the lands of the Appleton Land, Water and Power Company, probably few, if any, of the original units exceeded 320 acres, and some were only 160 acres. Some of the original tracts have been subdivided. Therefore, it seems sufficient to assume as an average that the riparian land does not extend back from the river more than one-half mile on either side. Considering only irrigable land and land where the flow is regular enough for crops to be matured, an estimate of 20,000 acres of riparian land is given. Adding to this another 20,000 acres for the Appleton company lands, the total estimated area of riparian lands that should be taken account of is about 40,000 acres.

As will appear from comparison of these acreage estimates and the figures in the chapter on "Water Supply," there is a far greater acreage in Mojave Valley having or in a position to claim water rights than can be supplied with the water available. Time at the disposal of the authors of this report did not permit an enumeration of the established or claimed rights. However, in connection with the reference above quoted (to the rights of the Appleton tract) the following statements are significant as indicative of the attitude of land owners whose old rights have remained dormant or been exercised only to a limited extent. They are from a communication filed in the spring of 1935 with the California Emergency Relief Administration in support of a project submitted to that agency for proposed early construction. (See also "Present Proposed Developments"):

"I desire to particularly invite your attention to the fact that owing to the great length of time the riparian and appropriation rights were filed on and approved, and also the entire absence of any adverse claims, and California Court Decisions affecting similar situations, it would be impossible for an outsider to construct any reservoirs, divert any of the water belonging to this property or to disturb the property water rights ....

"The riparian water rights of this property give it a minimum of 30,000 acre-feet per year."

Further reference to the matter of water rights, especially as affected by recent court decisions, is made in the chapter on "Present Proposed Developments."

QUALITY OF THE RIVER WATER 1/

The Mojave River drains the northern slopes of the San Bernardino Mountains, and its water in the upper part of its basin is very much like that of the upper tributaries of the Santa Ana River that drain the south slopes of the same mountains. These waters are remarkably pure and are well suited to irrigation use.

During the years 1932 and 1933 samples of water were collected at several stations along the Mojave River by Mr. K. R. Melin of the U. S. Geological Survey. These water samples were analyzed at the Rubidoux Laboratory of the U. S. Bureau of Plant Industry. The results of these analyses are reported in Table 15.

It will be observed that the data of the table are arranged in the order of the location of the sampling stations along the stream beginning at the headwaters of the main stream at the junction of West Fork and Deep Creek at approximately 3,000 feet elevation and extending thence downstream to a gaging station near Afton some 35 miles east of Barstow, including eight stations in all. At only two of these eight stations were samples taken more than once, but the data from the two stations that were sampled more than once indicate that the quality of the water does not change much with different volumes of discharge.

The station from which eight successive samples were taken is located in the Upper Narrows just above Victorville. Samples from this station, representing stream discharges ranging from 21 cubic-feet per second up to 82 cubic-feet per second, show that the total salinity as measured by conductance ($K \times 10^5$ @ 25° C.) did not exceed 30 nor drop below 20. Expressed in other terms this would mean that the total dissolved salts in this water is equivalent to approximately 0.2 ton per acre-foot, and the detailed analyses show that the most abundant constituent is calcium bicarbonate, a salt that is relatively harmless.

The detailed analyses reported in the table, for the stations as far downstream as Hodge, show that in respect to the various constituents as well as in sodium percentage the concentrations are well below the accepted limits of tolerance for irrigation use. The samples from the three lower stations are not quite so good, and particularly the sample from the Afton station shows concentrations that might be too high for safe use with some crops and under the less favorable soil conditions.

1/ By Carl S. Scofield, Principal Agriculturist in Charge, Division of Western Irrigation Agriculture, Bureau of Plant Industry, United States Department of Agriculture.

TABLE 15.- Quality of Mojave River water, as represented by samples collected in 1932, 1933, and 1934. (Analyses by Division of Western Irrigation Agriculture, United States Department of Agriculture, Riverside, California. Collection of samples and discharge data by United States Geological Survey.)

Lab. No.	Date	Discharge Sec.ft.	$K \times 10^5$ @ 25°C	Boron ppm	Sodium percent	Parts per million: Bicarbonate	Chloride	Sulphate	Calcium	Magnesium	Sodium
Junction of West Fork and Deep Creek (the Forks)											
5416	1- 5-32	40	16.5	0.03	23	76	4	4	17	5	9
Gaging Station in Upper Narrows - Victorville											
5417	1- 6-32	40	23.6	0.09	38	98	14	8	21	6	21
6758	10- 4-32	28	29.3	0.11	41	113	23	25	24	7	28
6911	11-16-32	35	25.6	0.06	37	113	17	18	24	6	23
7036	1-12-33	42	24.8	0.10	40	110	16	17	23	6	25
7268	4-14-33	34	23.1	0.07	35	113	13	20	20	7	20
7735	8-29-33	21	26.4	0.07	39	119	19	22	24	7	26
8183	12-27-33	39	24.4	0.08	38	119	9	9	23	5	23
8184	1- 3-34	82	20.8	0.04	38	110	9	4	19	5	20
Lower Narrows - Victorville											
5418	1- 6-32	45	25.8	0.11	33	107	14	6	22	6	19
Bryman - about 10 miles below Victorville											
5419	1- 6-32	45	30.6	0.14	34	137	14	12	28	6	23
Hodge - about 13 miles above Barstow											
5805	3-17-32	200	23.0	0.09	18	104	12	11	21	11	10
Forks of Road - about 16 miles below Barstow											
6098	4-27-32	1.6	65.8	0.18	45	247	48	85	59	13	75
6908	11- 2-32	0.5	60.0	0.16	54	162	53	93	37	11	75
7035	1-11-33	1	60.5	0.18	47	214	44	72	48	11	68
Camp Cady - about 25 miles below Barstow											
6518	7-21-32	0.5	54.0	0.26	60	214	48	45	33	7	77
Afton - about 35 miles below Barstow											
5598	1-29-32	2	164	1.88	90	381	222	283	25	7	383

The samples analyzed as recorded in Table 15 and identified there by laboratory numbers, have the following descriptions:

5416 MOJAVE RIVER at junction of West Fork and Deep Creek. NW corner of $NW\frac{1}{4}$, $SW\frac{1}{4}$, Sec. 18, T. 3 N, R. 3 W. Collected January 5, 1932, by K. R. Melin.

5417 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows at Victorville. $NW\frac{1}{4}$, $SE\frac{1}{4}$, Sec. 10, T. 5 N, R. 4 W. Collected January 6, 1932, by K. R. Melin.

6758 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows at Victorville. Local thunderstorm 3 days before but stream back to normal. Collector, K. R. Melin.

6911 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

7036 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

7268 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

7735 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

8183 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

8184 MOJAVE RIVER at U.S.G.S. Gaging Station in Upper Narrows. Collector, K. R. Melin.

River above normal after storm, but not a continuous stream.

5418 MOJAVE RIVER at Santa Fe R.R. bridge over Lower Narrows, about 2 miles below Victorville. $NW\frac{1}{4}$, $NW\frac{1}{4}$, Sec. 32, T. 6 N, R. 4 W. January 6, 1932, Collector, K. R. Melin.

5419 MOJAVE RIVER at Bryman, about 10 miles downstream from Victorville. Center N line, $NW\frac{1}{4}$, $NE\frac{1}{4}$, Sec. 25, T. 7 N, R. 4 W. January 6, 1932. Collector, K. R. Melin.

5805 MOJAVE RIVER at Hodge. Taken at U.S.G.S. Gaging Station, $SE\frac{1}{4}$, $SE\frac{1}{4}$, Sec. 28, T. 9 N, R. 3 W. Collected March 17, 1932, by K. R. Melin.

6098 MOJAVE RIVER at forks of road. (Watering place on Old Pioneer Trail.) NW corner $SW\frac{1}{4}$, Sec. 2, T. 9 N, R. 2 E. Stream is forced up by fault at this point. River dry above fault at this date. April 27, 1932, K. R. Melin.

6908 MOJAVE RIVER at forks of road. November 2, 1932, K. R. Melin.

7035 MOJAVE RIVER at forks of road. January 11, 1933, K. R. Melin.

6518 MOJAVE RIVER at Camp Cady. SW corner Sec. 19, T. 10 N, R. 4 E. Sample taken from stream above inflow from artesian wells. Surface flow at this point continuously. July 21, 1932, K. R. Melin.

5598 MOJAVE RIVER near Afton. At U.S.G.S. Gaging Station, Sec. 21, T. 11 N, R. 6 E. Collected January 29, 1932, by K. R. Melin.

WATER REQUIREMENTS OF IRRIGATED CROPS 1/

Most of the irrigated land in the Mojave Valley lies adjacent to the river or in territory served by underflow from the same source. The few records of irrigation of alfalfa available in the Victorville district (see Table 16) show an application of about 9 acre-feet per acre annually, a high figure which is, however, equalled elsewhere, especially in sandy bottom soils farther down the valley where pumping lifts are low or gravity water is available.

The use of water on alfalfa at points distant from the river bottom where irrigation is entirely by pumping from wells through relatively high lifts is less than under gravity diversions.

TABLE 16. - Irrigation water applied to alfalfa in Victorville district, Mojave Valley, Calif., May, 1934-April, 1935 1/

Area irrigated	Total irrigation water applied per acre	Crop	Locality
Acres	Acre-feet		
41	3.17	1 acre alfalfa, 40 acres fruit	Apple Valley
90	3.39	45 acres alfalfa, 45 acres barley hay	Apple Valley
50	9.40	50 acres alfalfa	Victorville
20	8.75	20 acres alfalfa	Oro Grande
40	8.75	40 acres alfalfa	Helendale
70	10.49	70 acres alfalfa	Wild
36	3.45	21 acres alfalfa, 15 acres grain	Hinkley
50	5.26	50 acres grain	Hinkley

1/ These data obtained from the farmers through the Southern Sierras Power Company.

1/ Prepared principally by A. A. Young, Assistant Irrigation Engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

The best records of irrigation of alfalfa in areas adjoining the Mojave Valley are those obtained near Lancaster, some 40 miles west of Victorville. The climate in each case is similar except that precipitation at Lancaster probably exceeds slightly that along the Mojave River. Records of irrigation by pumping, obtained by the Agricultural Extension Service, University of California, near Lancaster in the Antelope Valley, are given in Table 17. The mean use of water for the years 1931 and 1932 was 5.5 acre-feet per acre, not including rainfall. Additional records kept by J. A. Bradley on the Mileaway Ranch in the same vicinity show an average use of pumped water amounting to 6.82 acre-feet over a 5-year period. (Table 18.)

Preliminary investigations of irrigation of alfalfa in Antelope Valley disclosed that between 9 and 10 acre-feet per acre were being used on a number of ranches. Following irrigation demonstrations by county farm advisors and extension specialists the average use of water dropped to between 7 and 8 acre-feet in the following year and to 5-1/2 acre-feet in 1931 and 1932, without decreasing the yield. With further educational and economic pressure it is probable that the use of water can be still further reduced. What has been done along this line in the Antelope Valley ought to be possible in Mojave Valley also. Among several influences now operating to cause a heavier use than is perhaps necessary two may be mentioned here. Control of both should effect an appreciable reduction in water use: (1) Checks are too large and irrigating heads inadequate, thus necessitating an almost continuous irrigation schedule and a total application of more water than should be needed were checks reduced in size. Five cuttings of alfalfa are commonly made, but the number of irrigations varies from about eight or 10 to as many as 20. (2) Unnecessarily heavy irrigations are made just before May 1, when the electrical rate year changes and while the lowest rate is applicable. What looks like a bargain rate for pumping tempts many farmers to make too heavy an application.

Records of irrigation outside of the Mojave and Antelope valleys have been obtained at the Yuma Field Station, Bard, California, by the Division of Irrigation, Bureau of Agricultural Engineering, U. S. Department of Agriculture. These are shown in Table 19. The growing season at Bard is longer than at Victorville and temperatures are higher, both of which influences should contribute to a heavier use of water at Bard. Nevertheless, the average use by mature alfalfa for the 3-year period, 1932-33 and 34, was only 5.4 acre-feet per acre, a figure which corresponds closely with that for Antelope Valley.

The quantities of water mentioned in the preceding tables are total amounts of irrigation applied, but do not include rainfall which occurs mostly during the winter months and is distributed during the season so as to be of little value to a growing crop. They include the net consumptive use of water withdrawn from the soil by the crop as well as any excess water which may percolate downward beyond the limits of the root zone.

TABLE 17. - Irrigation water applied to alfalfa grown in the Lancaster Area, Antelope Valley, Calif., 1931-32

Soil type	1931 1/		1932 2/	
	Area irrigated	Total irrigation application per acre	Area irrigated	Total irrigation application per acre
	Acres	Acre-feet	Acres	Acre-feet
Fine sand	72	5.81	65	3.10
Loamy sand	45	4.40	30	3.65
" "	45	4.50	75	3.88
--	80	1.19	--	4.30
Sand	60	7.78	--	5.00
"	25	9.62	--	5.02
Fine sandy loam	24	5.47	--	5.47
--	4	2.20	40	5.68
Sand	75	5.77	38	5.75
"	60	6.78	35	6.07
Sand, heavy	33	8.36	62	6.11
Loamy sand	38	8.20	65	6.65
Fine sandy loam	35	4.60	70	6.74
Sand	10	6.03	40	7.97
Fine sandy loam	153	5.19	25	8.11
Sand	15 3/	4.27		
"	10 3/	8.61		
--	40 3/	9.75		
--	78 3/	4.86		
Loamy sand	30 3/	2.94		
Fine sandy loam	14 3/	4.22		
--	77 3/	4.35		
Sand, heavy	5 3/	2.80		
--	45 3/	4.94		
Mean		5.53		5.56

1/ 2/ Obtained by County Farm Advisor, Agricultural Extension Service, University of California, from individual growers.

1/ Published in Tech. Bulletin No. 379, "Irrigation Requirements of the Arid and Semiarid Lands of the Pacific Slope Basins," by Samuel Fortier and Arthur A. Young.

2/ Mimeographed reports in Los Angeles County Farm Advisor's office.

3/ These fields were newly planted in the fall of 1930.

TABLE 18. - Amounts of irrigation water applied per acre to alfalfa on the Mileaway Ranch, Lancaster, Antelope Valley, Calif., 1929 to 1933, inclusive

Year	Area irrigated	No. of irrigations	Feb.15 to Mar.15	Mar.15 to Apr.15	Apr.15 to May 15	May 15 to June 15	June 15 to July 15	July 15 to Aug. 15	Aug. 15 to Sept.15	Sept.15 to Oct. 15	Oct.15 to Nov.15	Nov.15 to Dec.15	Total irrigation application
	Acres		Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.	Ac.ft.
1929	20.5	10	0.29	0.28	0.33	0.68	1.30	1.41	1.71	1.14	0.72	0.14	8.00
1930	34.0	9	.09	.65	.62	.80	1.08	1.09	1.50	.13	--	.70	6.66
1931	34.0	8	--	.90	.75	.87	1.22	1.00	1.05	.70	.01	--	6.50
1932	34.0	8	--	1.33	.31	.74	1.03	1.20	1.06	.36	.01	--	6.04
1933	26.75	11	.37 1/	1.02	.55	.81	1.24	1.04	1.01	.80	.07	.01	6.92
Mean			.15	.84	.51	.78	1.17	1.15	1.27	.63	.16	.17	6.82

1/ Includes 0.22 acre-feet per acre applied during winter months.

Remarks:- Soil on this ranch ranges from sand through sandy loam to loam. Compiled from report by J. A. Bradley, Santa Ana, California.

TABLE 19. - Comparison of duty of water used on experimental plots at U. S. Yuma Field Station, Bard, Calif., 1932-33-34

Crop	Year	Length of irrigation season	Number of irrigations	Average depth of application per irrigation	Total irrigation application per acre
		Days		Inches	Acre-inches
Mature alfalfa	1932	336	14	3.86	58.82
	1933	342	16	4.57	70.96
	1934	287	14	4.60	64.36
Young alfalfa	1932	329	17	3.19	55.52
	1933	319	18	3.60	63.70
	1934	309	17	4.03	68.54
Barley	1932	153	6	3.68	22.10
	1933	146	6	4.08	23.39
	1934	135	6	3.70	22.17
Corn	1932	101	8	3.46	28.16
	1933	98	6	5.21	31.24
Grain sorghum	1932	117	8	3.77	29.92
	1933	110	8	4.14	31.01
	1934	106	6	3.95	23.72
Winter wheat	1932	153	5	3.51	17.54
" "	1933	147	5	4.50	22.48
Spring wheat	1934	85	4	3.36	13.43

Water thus passing to depth is of no value to the crop at the time, but to a certain extent, depending upon conditions described later, becomes available for future use through return flow.

Where five, six or more acre-feet per acre are used in irrigation of alfalfa some part of the water must pass below the root zone. Amounts used consumptively depend in part upon such factors as density of stand, length of growing season, climatic factors, and number of cuttings. As far as known, actual consumptive use of water by alfalfa in this area has never been determined and any estimate used in this report can be merely approximate. Experiments made by the Division of Irrigation, Bureau of Agricultural Engineering, during May, June, and July, 1930, on consumptive use of water by alfalfa grown in the Chino basin under slightly different climatic conditions have been described. 1/ The results were as shown in Table 20. These data are fragmentary but are shown here for whatever value they may have:

TABLE 20. - Consumptive use of water, alfalfa plot, Thomas Ranch, Chino, 1930

Date of irrigation	Date crop was cut	Period studied	Rate of use per 30 days
			Acre-inches
--	May 12	May 12-May 23	4.03
May 26	--	June 7-July 1	5.50
July 12	July 18	July 21-Aug. 4	3.54
Aug. 6	Aug. 21	--	--
Sept.12	--	--	--
Total			13.07

Return flow also depends upon a number of factors, chief of which are quantity of water applied, consumptive use by crops, porosity of soil irrigated, and length of period during which the area has been under irrigation. If it be assumed that consumptive use by alfalfa is 3 acre-feet per acre as estimated by Conkling in Bulletin 47, and 6 to 9 acre-feet are used in irrigation the return flow will be increased by 3 to 6 acre-feet. As previously explained, a definite figure for consumptive use by alfalfa is not known and can only be estimated.

1/ California State Department of Public Works, Division of Water Resources, Bulletin 33, "Rainfall Penetration and Consumptive Use of Water in the Santa Ana Valley and Coastal Plain," by Harry F. Blaney, C. A. Taylor and A. A. Young, 1930.

As some deciduous fruits are still grown in Mojave Valley, available records of use of water by orchards have been compiled. Table 21 shows amounts of water used in irrigating deciduous orchards in various localities not all of which are in the Mojave area. Data shown are not always consistent, as one mature orchard on East Mesa was given more than twice as much irrigation as one in the river bottom lands. Some localities have more rainfall than others, which also affects the amount of irrigation necessary.

TABLE 21. - Irrigation water applied to deciduous orchards 1/

Locality	Number of orchards	Total acres	Total irrigation application, per acre
			Acre-feet
2/			
Mojave River bottom	1	6	1.98
East Mesa	7	480	.89
West Mesa	6	195	.31
Lucerne Valley	3	68	.88
Yucaipa	1	10	.36
Perris Valley	3	30	.68
Beaumont	2	18	.40
3/			
Mojave River bottom	1	15	2.55
East Mesa	1	30	5.72
West Mesa	5	70	1.02
Yucaipa	3	29	2.12
San Timeteo Canyon	2	35	.41
Beaumont	10	154	.38
Banning	8	138	1.80

1/ From Tables 11 and 12, State Bulletin No. 5.
2/ This group of orchards under five years of age.
3/ This group of orchards over five years of age.

The best record of irrigation of pears was found in the Littlerock Creek Irrigation District between Palmdale and Victorville. This district is closer to the mountains than much of the Mojave Valley and probably has more rainfall. Records from 26 pear orchards are compiled in Table 22, which gives the total irrigation application during the season as well as its monthly distribution. Actual use of water on 26 orchards comprising 303 acres was 17.2 acre-inches per acre, which may be considered very moderate irrigation. These orchards were clean

cultivated. Table 23 shows monthly and seasonal irrigations on 16 orchards on which some cover crops of alfalfa were grown between trees. Under these conditions more irrigation is necessary. Sixteen orchards totaling 124 acres used 24 acre-inches per acre. Such records give a fair indication of irrigation practices in an area climatically similar to Mojave Valley. They show that orchards can grow and become productive on small amounts of water. Water in the Littlerock District is stored in a reservoir and supplemented to a very limited extent by water pumped from wells.

Monthly and seasonal net irrigation requirements of Antelope and Mojave valleys have been estimated.[1] In groupings of this kind primary considerations are climate, crops, and scarcity of water. In localities having a limited water supply of high value preventive wastes are reduced to a minimum. As the difficulty of securing water increases growers are inclined to turn to those crops which may be produced with less irrigation; but, as has been shown elsewhere in this report, the trend in Mojave Valley has been strongly away from orchards and into an expansion of the alfalfa acreage. If alfalfa remains the principal crop the net requirement must be considered approximately 3.0 acre-feet per acre. Many farmers will use more water, but with careful attention to modern irrigation practice excessive use can be reduced.

The monthly percentage of net irrigation requirement as given in Bulletin No. 379 is as follows:

Month	Percent
March	3
April	10
May	16
June	18
July	20
August	18
September	10
October	5
Total	100

[1] Irrigation Requirements of the Arid and Semiarid Lands of the Pacific Slope Basins, U. S. Dept. of Agriculture Tech. Bul. No. 379, by S. Fortier and A. A. Young, 1933.

TABLE 22. - Irrigation water applied in the Littlerock Creek Irrigation District, Antelope Valley, Calif., 1934

Area irrigated	Crop	Number of irrigations	Monthly application of water per acre								Total irrigation application, per acre
			March	April	May	June	July	August	Sept.	Oct.	
Acres			Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.
10	Pears	5	--	3.84	3.84	3.84	3.84	3.84	--	--	19.2
20	"	3	--	--	3.84	3.84	3.84	--	--	--	11.5
18	"	5	--	4.00	4.26	4.00	3.73	--	4.26	--	20.2
10	"	4	3.84	--	3.84	--	3.84	3.84	--	--	15.4
10	"	6	--	3.84	1.92	3.84	3.84	3.84	3.84	--	21.1
5	"	5	3.84	--	3.84	3.84	3.84	3.84	--	--	19.2
9	"	4	--	4.27	4.27	--	4.27	--	4.27	--	17.1
20	"	3	--	3.84	--	3.84	--	--	--	3.84	11.5
10	"	6	3.84	--	3.84	3.84	3.84	3.84	3.84	--	23.0
10	"	4	--	--	3.84	3.84	3.84	3.84	--	--	15.4
10	"	5	--	3.84	3.84	3.84	3.84	3.84	--	--	19.2
20	"	5	--	3.84	3.84	3.84	3.84	--	--	3.84	19.2
17	"	3	--	3.67	3.95	--	3.95	--	--	--	11.6
10	"	3	--	1.92	--	1.92	1.92	--	--	--	5.8
10	"	4	--	--	--	7.68	3.84	--	3.84	--	15.4
4	"	5	--	3.60	3.60	3.60	3.60	--	3.60	--	18.0
8	"	5	4.80	--	4.80	4.80	4.80	--	4.80	--	24.0
20	"	5	--	3.84	3.84	3.84	3.84	--	3.84	--	19.2
10	"	3	--	--	3.84	3.84	--	3.84	--	--	11.5
10	"	5	--	3.84	3.84	3.84	3.84	3.84	--	--	19.2
10	"	5	--	3.84	3.84	3.84	3.84	--	3.84	--	19.2
12	"	5	3.84	--	7.68	3.84	3.84	--	--	--	19.2
10	"	4	--	3.84	3.84	--	3.84	--	3.84	--	15.4
10	"	7	3.84	3.84	3.84	3.84	3.84	3.84	3.84	--	26.9
10	"	3	--	3.84	--	3.84	3.84	--	--	--	11.5
10	"	5	--	3.84	3.84	3.84	3.84	--	--	3.84	19.2
303	MEAN	4.5	0.92	2.44	3.39	3.36	3.51	1.48	1.68	0.44	17.2

TABLE 23. - Irrigation water applied in the Littlerock Creek Irrigation District, Antelope Valley, Calif., 1934

Area irrigated	Crop	Number of irrigations	Monthly application of water per acre								Total irrigation application, per acre
			March	April	May	June	July	August	Sept.	Oct.	
Acres			Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.	Ac.in.
10	Pears 1/	4	--	3.84	--	3.84	3.84	3.84	--	--	15.4
10	" 1/	4	--	--	3.84	3.84	--	3.84	--	4.32	15.8
7	" 1/	5	--	5.48	14.40	8.23	--	8.23	--	--	36.3
10	" 1/	7	--	3.84	3.84	3.84	3.84	3.84	3.84	3.84	26.9
10	" 1/	5	--	3.84	3.84	11.52	3.84	--	--	--	23.0
5	" 1/	3	--	3.84	--	3.84	3.84	--	--	--	11.5
5	" 1/	3	3.84	--	--	3.84	3.84	--	--	--	11.5
12	" 1/	7	--	3.84	3.84	3.84	7.68	3.84	3.84	--	26.9
5	" 1/	4	3.84	--	--	3.84	3.84	--	5.76	--	17.3
10	" 1/	4	--	3.84	3.84	3.84	--	3.84	--	--	15.4
10	" 1/	3	3.84	--	--	3.84	3.84	--	--	--	11.5
10	" 1/	8	--	5.76	4.80	4.80	9.60	3.84	3.84	--	32.6
5	" 1/	3	--	3.84	--	3.84	3.84	--	--	--	11.5
5	" 1/	7	--	3.84	3.84	3.84	3.84	3.84	7.68	--	26.9
5	" 1/	5	--	7.68	7.68	3.84	--	--	--	--	19.2
5	" 1/	5	--	7.68	7.68	3.84	--	--	--	--	19.2
10	Mixed fruits	6	7.68	--	7.68	7.68	3.84	--	--	--	26.9
5	Peaches	8	3.84	--	3.84	3.84	7.68	3.84	3.84	3.84	30.7
2½	Kaffir corn	7	--	7.68	5.76	3.84	3.84	3.84	3.46	--	28.4
5	Alfalfa	6	--	1.92	1.92	1.92	1.92	3.84	--	--	11.5
5	"	6	--	3.84	3.84	3.84	7.68	3.84	--	--	23.0

1/ These pear orchards grew some alfalfa between the trees as a cover crop, not commercially.

COST OF PUMPING[1]

The cost of delivery of irrigation water varies with the means employed. Easy diversions from flowing streams delivered through small canal systems result in low costs. Pumping for irrigation results in high costs. Where there is no surface supply and pumping is necessary, items making up the cost of pumping are directly under the farmer's control. Such costs depend, in part, on the type of well, on a pump suitable for meeting irrigation demands economically, and upon the source of power to run the pump. In addition, the farmer is sometimes able to choose those crops which use small amounts of water thus holding his power bills to a minimum.

The pumping unit consisting of pump and engine or motor is most economical in operation when direct connected, thus saving transmission losses and improving efficiency. Plants with less than 50 percent efficiencies are not economical although many are used. According to the county farm advisor of Los Angeles County the actual value of each 1 percent difference in plant efficiency in ten cases where comparisons could be made was found to be 9.9 cents per acre-foot per 100 feet of lift. For this study the range of plant efficiency was between 45 and 55 percent. On the average the grower who operates a 45 percent efficient plant with a lift of 100 feet pays 99 cents more per acre-foot for electric power than if his plant had a 55 percent efficiency, assuming that both plants would run about the same number of hours per season. When efficiencies are less than 50 percent it will be found economical to replace or repair worn parts.

The cost of pumping may be divided into depreciation, interest, taxes, and insurance, power or fuel charges, lubrication, repairs, and attendance.[2] These include both operating and fixed charges. The choice of power or fuel lies with the operator and may be either gasoline, Diesel fuel oil, natural gas, or electric power. Where the latter is available it is generally used on account of its cheapness, convenience, and dependability. Mojave Valley is served by the Southern Sierras Power Company whose agricultural power schedule is given in Table 24.

Using data obtained by the Southern Sierras Power Company in making pump tests, and combining them with yearly records of cost and operation, Table 25 has been compiled to show some costs of pumping for irrigation at nine different pumping plants in Mojave Valley. Lifts varied from 21 to 262 feet at the time the pumps were tested. No continuous records of water levels are available and it should be understood that seasonal variations in water levels have not been considered.

1/ Prepared principally by A. A. Young, Assistant Irrigation Engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

2/ California State Department of Public Works, Division of Water Resources, Bulletin No. 36, "Cost of Irrigation Water in California," by Harry F. Blaney and Martin R. Huberty.

Only meager pumping costs for the Mojave Valley are thus available,[1] but power costs for pumping for alfalfa in the Antelope Valley have been found by the Los Angeles county farm advisor. As the two areas are similar in soil and climate Table 26 is included. Records of 29 farms are shown, giving annual power costs per acre, per acre-foot, and per ton of hay. Analysis of the first group of records in the table shows that those plants having an average overall efficiency of less than 50 percent cost $3.19 per acre-foot of water pumped, while those with an efficiency of over 50 percent cost $2.01 per acre-foot.

Additional pumping records are available for the Mileaway Ranch in the Antelope Valley for the 5-year period 1929 to 1933, inclusive, as shown in Table 27. Although the Antelope Valley is served by the Southern California Edison Company, the power rates, while differing slightly from those in the Mojave Valley, agree closely enough so that pumping costs under the two systems may be compared. However, pumping lifts in the Antelope Valley are probably greater than those in the Mojave area.

The economic lift in pumping for irrigation depends, in part, on the type of crop grown, the cost of its production, and the value it will have when sold. Among other items in cost of production are power charges, pumping lift, water pumped, and plant efficiency. High-priced specialty crops, especially those with low water requirements, can stand higher pumping costs than crops bringing smaller returns. Citrus, using two acre-feet per acre, may and sometimes does receive water pumped through lifts of as much as 500 feet on account of the high sale prices for the crops. Alfalfa, on the other hand, with a greater water requirement and receiving smaller returns, must have its pumping charges sharply limited if the grower is to receive a profit. In many cases growers have failed to realize the necessity for better irrigation practice in order that power bills may be reduced and that some of the value received may be retained as a profit. In recent years too many alfalfa growers have operated at a loss. In part, this is attributable to economic conditions, but in many cases it is also a result of poor irrigation practice.

1/ The 1931 alfalfa efficiency studies discussed under the heading, "Costs of and Returns from Farming," showed an average cost for "irrigation water" of $11.36 per acre. (This was a material cost -- not labor.) The 1930 average was $13.00, and the 1929 average $12.06. The 1930 report calls particular attention also to the fact that, for that year, "the total average cost of irrigation per acre is $35.00." The figures on cost of irrigation water are understood by the authors to differ from those shown in Table 25 because they include other items besides power, such as lubrication and repairs.

TABLE 24. - Southern Sierras Power Company, Agricultural Power Service, Schedule P-4, Mojave District

Rate (a) - For service delivered at 110, 220, or 440 volts

Annual consumption per horsepower	Rate per K.W.H. for connected loads of		
	2 H.P. to 9 H.P.	10 H.P. to 24 H.P.	25 H.P. and over
	Cents	Cents	Cents
First 500 K.W.H.	2.5	2.4	2.3
Next 500 K.W.H.	2.1	1.9	1.6
Next 1000 K.W.H.	1.35	1.3	1.1
Next 2000 K.W.H.	1.1	1.1	0.95
Over 4000 K.W.H.	0.95	0.95	0.85

Minimum charge:
First 5 H.P. @ $9.50 per H.P. per year but not less than $24 per year.
Over 5 H.P. @ $8.00 per H.P. per year.

Rate (b) - Optional with above rate (a)

Energy charge per H.P. per year in addition to demand charge	Demand charge per H.P. per year For connected loads of		
	2 H.P. to 9 H.P.	10 H.P. to 24 H.P.	25 H.P. and over
	Dollars	Dollars	Dollars
	9.50	8.50	8.50
	Cents	Cents	Cents
First 2000 K.W.H.	1.35	1.3	1.1
Next 2000	1.1	1.1	0.95
Over 4000 K.W.H.	0.95	0.95	0.85

TABLE 25. - Cost of power for irrigation by pumping, Mojave Valley, California, 1934-35 1/

Location	Crop	Size of plant	Overall efficiency	Power consumption	Duration of pumping operation	Total pumping head	Water pumped	Total power cost	Power cost		
									Per acre	Per acre-foot	Per acre-foot per foot lift
		H.P.	Percent	K.W.H.	Hours	Feet	Ac.ft.	Dollars	Dollars	Dollars	Cents
Wild	Alfalfa	10	54	25460	4515	21	734	417.32	5.97	0.57	2.7
Helendale	Alfalfa	5	45	20828	2865	27	350	320.53	8.01	0.92	3.4
Oro Grande	Alfalfa	7½	54	10094	1558	30	175	221.86	11.09	1.27	4.2
Victorville	Alfalfa	7½	47	26421	3731	26	470	429.48	8.59	0.91	3.5
Apple Valley	Alfalfa - Barley hay	15	57	36670	3099	62	305	619.32	6.88	2.03	3.3
Apple Valley	Deciduous fruits	30	58	60000	1925	262	130	909.21	22.17	6.97	2.7
Hinkley	Alfalfa - grain	10	44	16360	1361	55	124	304.06	8.46	2.45	4.5
Hinkley	Grain	10	54	17876	2338	55	170	303.41	--	1.53	2.8
Hinkley	Grain	20	53	9380	672	52	94	185.82	--	1.99	3.8

1/ These data obtained from the farmers through the Southern Sierras Power Company.

TABLE 26. - Cost of power for irrigation of alfalfa by pumping
Antelope Valley, California

Overall efficiency	Duration of pumping operation	Total pumping head	Water pumped per acre	Power cost		
				Per acre	Per acre-foot	Per ton
Percent	Hours	Feet	Ac.-ft.	Dollars	Dollars	Dollars
--	1937	Average pumping lift 95 ft.	4.40	12.70	2.86	2.24
48	2507		4.50	13.28	2.95	1.67
48	2410		4.60	18.68	4.07	2.68
44	3126		5.19	13.08	2.28	2.36
--	3446		5.47	21.50	3.93	2.76
52	4364		5.77	12.03	2.08	2.04
44	3394		5.81	16.23	2.79	2.44
47	1374		6.03	23.16	3.84	4.83
58	4097		6.78	13.39	1.98	2.08
61	1900		7.15	13.54	1.89	2.07
53	2038		7.78	12.21	1.57	2.12
61	2692		8.20	18.37	2.24	2.56
--	2326		8.36	18.26	2.18	2.82
50	1853		9.62	22.32	2.32	4.68
51	1311	111	3.10	16.94	5.48	4.16
--	1677	100	3.65	17.48	4.80	3.04
54	2177	119	3.88	11.10	2.86	1.70
56	2223	113	4.30	11.26	2.62	--
45	4388	114	5.00	12.76	2.55	--
34	3196	88	5.20	18.94	3.66	--
52	3408	104	5.47	11.65	2.13	--
LOW	2725	100	5.68	13.81	2.43	2.39
62	2850	112	5.75	13.43	2.17	1.88
44	2137	104	6.07	19.19	3.16	3.27
62	1103	110	6.11	22.53	3.69	4.51
53	2454	60	6.65	9.76	1.46	2.19
57	3656	113	6.74	13.19	1.96	2.16
59	1947	146	7.97	26.95	3.38	3.65
49	1926	90	8.11	13.30	1.64	2.30

Power furnished by the Southern California Edison Company.
The first group of records were obtained in 1931, the second group in 1932.
All data were collected by the county farm advisor, Agricultural Extension Service, University of California.

TABLE 27. - Cost of power for irrigation of alfalfa by pumping, Mileaway Ranch, Antelope Valley, California

Year	Overall efficiency	Total K.W.H.	Total pumping head	Water pumped per acre	Power cost	
					Per acre-foot	Per ton
	Percent		Feet	Ac.ft.	Dollars	Dollars
1929	57	29610	100	8.0	3.09	4.61
1930	57	40210	98	6.7	2.58	3.50
1931	58	34370	89	6.5	2.32	2.50
1932	58	31990	88	6.0	2.40	2.46
1933	54	35270	88	6.9	2.47	2.96

Power furnished by the Southern California Edison Company.
Data furnished by J. A. Bradley, Santa Ana, California.

WATER SUPPLY[1]

Description of Mojave River System

The drainage basin of Mojave River is an irregular-shaped area that extends from the southwestern part of San Bernardino County northeastward to the central part of the county. Despite its various peculiarities Mojave River is a typically desert river in its lower courses. It rises in the high San Bernardino Mountains where it is perennial. Within a short distance it emerges on the desert plain, and much of the water sinks into the porous alluvium so that it is entirely dry throughout much of its course for many months at a time.

The mountain headwaters comprise two distinct branches, East Fork, or Deep Creek, and West Fork, which unite at the base of the mountains to form the main river. This junction is known as the Forks. Below it the river, in its course of 90 miles across the desert plain, receives no surface tributary of consequence, but there is an underground contribution from springs. The course of the river is first northward 30 miles, then northeastward 20 miles, and finally eastward 40 miles. The river ends in dry lakes at an elevation of less than 1000 feet above sea level. The mountain watershed of the river, 217 square miles in area, extends from an elevation of 8000 feet at the summit of the range to 3000 feet at the Forks. The upper portion has heavy precipitation and the main tributaries are never dry where they leave the mountains. In summer the water sinks in the river a short distance below the Forks but appears again as surface flow several miles downstream, reaching the Upper Narrows at Victorville, 14 miles below the Forks. The surface flow continues through the Lower Narrows 4 miles farther downstream, and during the summer again sinks several miles below Oro Grande after supplying a number of irrigation ditches. The water is then brought to the surface for short distances at a number of other points. These points are increasingly farther apart and the flow diminishes in quantity toward the lower end of the stream. At each place of reappearance the water supports a considerable amount of noneconomic vegetation. In describing these points in the river, Thompson[2] states:

> "Wherever the water is at or close to the surface there is more or less evaporation, not only from the surface streams but also from the ground water supply through direct upward capillary movement and by transpiration from the plants. In some places as summer approaches the evaporation becomes so great that the water is disposed of more rapidly than it reaches the surface, and the stream dwindles and disappears. But even when the stream no longer exists water is generally present a few feet below the surface, except in places where the ground water is not held near the surface by submerged rock 'dikes' or dams. As the end of the

1/ Taken in part from State Bulletins No. 5 and No. 47.
2/ U. S. Geological Survey W. S. Paper 578, p. 375.

dry season approaches the evaporation becomes less, more water reaches the surface and the stream becomes wider and deeper and has a greater linear extent. The end of the stream may be seen to advance on cool days and at night and to retreat on warm days."

In dividing the Mojave River stream system into various areas for study, certain natural segments become self evident. Above the Forks, the area is mountainous and produces practically the entire water supply. Between the Forks and the Upper Narrows at Victorville is a capacious absorption area, the seepage losses into which are either lost by evaporation and transpiration, or become surface flow at the natural dam created by the Upper Narrows constriction. The amount of underflow through the Upper Narrows is negligible. From the Upper Narrows to Hodge, the stream flows in a narrow canyon-like section. The surface flow at the Upper Narrows supplies a constant gravity flow for several ditches in the upper reaches of this section, but the rest of the area must depend for water on pumping from the gravels along the stream. Below Hodge there is another absorption area, not quite so good as the area between the Forks and Upper Narrows, because the stream-bed materials are not so coarse. In this section, which extends to Barstow, there is an underground escape of an indefinite quantity of water under Hinkley Valley toward Harper Lake.

Between Barstow and Daggett, the stream flows in a section similar to that between Upper Narrows and Hodge. Below Daggett, there is a broad alluvial flat sloping in a general easterly direction. The stream flows in an ever deepening trench along the northerly side of this valley to Camp Cady, where it enters a deeply eroded narrow channel in which it flows to the vicinity of Baxter on the Union Pacific Railroad. Below Baxter, there is a broad debris cone, which is very absorptive. The stream flow, which occurs during times of flood at infrequent intervals, wanders over this debris cone on which it splits into two diverging channels, one channel carrying water northerly into East or Upper Cronise Valley where a lake has been formed and at the northerly end of which overflow through a low gap would carry the water to another basin known as West or Lower Cronise Valley. The other channel carries the water easterly into Soda Lake, a broad alkali flat which offers no surface storage, but over which the flood flow spreads for a considerable area, saturating the soil from which it later evaporates. At the lower end of Soda Lake the remaining flow re-gathers and passes through a low, narrow gap into Silver Lake, which at present is the extreme end of the Mojave River stream flow. There is direct evidence that Silver Lake has overflowed during recent times, in which case the water would reach the Amargosa River near Salt Spring and thence by this channel reach the Salt Pools in the bottom of Death Valley.

For the purpose of discussing the water supply of the Mojave Basin, the basin may be divided into five parts: (1) the mountain headwaters (see Plate 5-A in Appendix); (2) the Upper Mojave Valley, a broad alluvial plain, extending from the San Bernardino Mountains northward to Victorville, (see Plate 5-A in Appendix); (3) the Middle Mojave Valley, a narrow irregularly shaped alluvial plain, extending from Victorville to a point near

Barstow, (see Plate 5-B in Appendix); (4) the Lower Mojave Valley, a broad triangular shaped alluvial plain, having its vertex at a point near Daggett and its base at Cady Mountain, (see Plate 5-C in Appendix); and, (5) the region to the north and east of Cady Mountain, commonly known as the sink of the Mojave River, occupied by Cronise, Crucero, and Soda Lake valleys.

Mountain Headwaters

The headwater region of the Mojave Basin above the Forks forms a collecting area for the water of both the surface flow of Mojave River and a large part of the ground water of different parts of Mojave Valley.

The headwaters drain practically all the north slope of San Bernardino Mountains. The drainage area is forested in its higher elevations and much of the precipitation occurs as snow. The headwaters comprise two major branches, West Fork, 75 square miles, and East Fork (Deep Creek), 137 square miles, above stream gaging stations which unite head-on just above the plain at the Forks and form the Mojave River.

As a result of the activities of the Arrowhead Lake Corporation (and its predecessors), data on rainfall and runoff are unusually numerous for the headwaters of Mojave River, and it is possible to estimate the discharge of the tributaries at numerous points. These records were made available to the California State Division of Water Resources and were used by their engineers as the basis for estimates of discharge at various places. Since 1930 the United States Geological Survey has been measuring the discharge of the East and West Forks of Mojave River. The results are incorporated herein.

Precipitation. - The northern slopes of the Sierra Madre Range receive less precipitation than the southern slopes, but they are less steep, less subject to direct rays of the sun, better timbered, and they hold the snows longer and have slower runoff in proportion to precipitation than southern slopes.

The comprehensive meteorological observations made throughout the watershed by the Arrowhead Lake Corporation and others for many years show the precipitation to vary from about 13 inches at the Forks to about 58 inches near the summit, the maximum occurring in the flats situated just north of the crest of the range. The precipitation falls off rapidly toward the desert on the northeast. The more elevated portions of the watershed are in heavy timber of pine and fir without much undergrowth, and the lower portions are covered with thick brush.

Monthly and annual precipitation records are shown in Appendix 1, Table 39, and locations of stations are indicated on Plate 2 of California State Bulletin No. 47, "Mojave River Investigation." From the records of 50 years (beginning 1883-84), the average rainfall at the several stations, where the record is more than 10 years in length, is estimated to be as shown in Table 28:

PLATE 2

COMPARISON OF PERCENT OF MEAN ANNUAL DISCHARGES OF MOHAVE AND SANTA ANA RIVERS

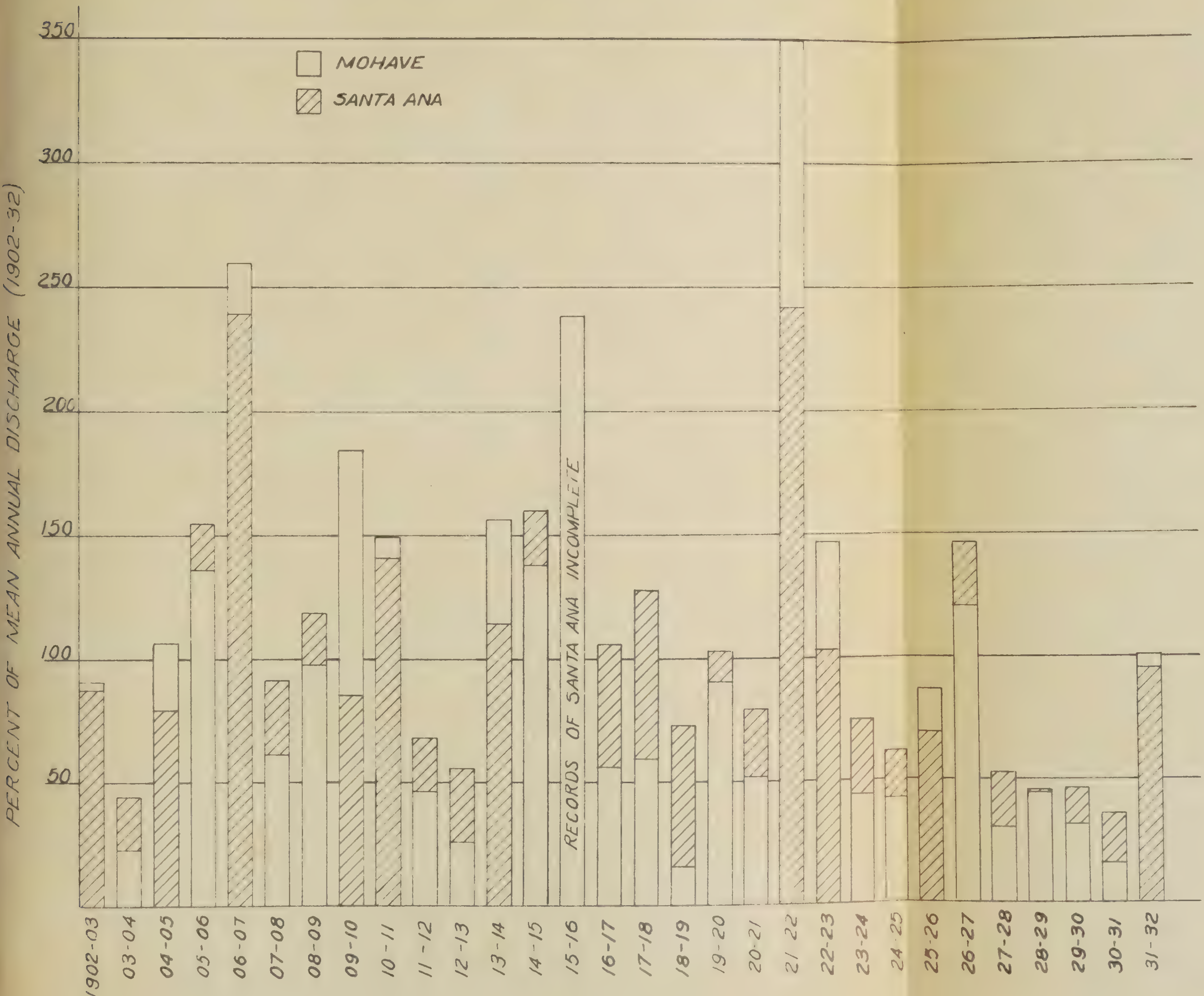


TABLE 28. - Precipitation at principal stations maintained by Arrowhead Lake Corporation and others in and near mountain headwaters of Mojave River

Station	Elevation above sea level	Length of record	Estimated 50-year mean
	Feet	Years	Inches
Ash Meadows	4650	10	23.75
Big Bear Lake Dam 1/	6800	50	38.27
Deep Creek	5200	17	34.58
Forks of Mojave	3000	16	13.17
Gate House in Little Bear Valley	5100	33	36.40
Grass Valley at Saw Mill	5190	12	41.37
Hesperia 2/	3190	10	8.18
Holcomb Creek	5250	16	24.46
Morse's	5350	21	58.07
Squirrel Inn	5280	29	46.31
Victorville 2/	2716	15	5.21

1/ In headwaters Santa Ana River.
2/ In Mojave River Valley.

Stream discharge. - The drainage of the mountain watershed of the Mojave River is brought together in the main river at the Forks. Although there have been no stream measurements made at this point, gaging stations have been maintained in the East Fork and West Fork just above the Forks and records are available for some years. These, together with precipitation and other stream-flow records, have been used by various engineers in estimating the flow of the river at the Forks before it enters the Valley Area. Table 29 is a comparison of some of these estimates.

Some years show considerable differences. This is due primarily to the fact that in some instances the estimates are based on precipitation records, while in others stream-flow records from different watersheds are used as a basis. However, these differences tend to be smoothed out when a period of several years is considered. Estimates are bound to vary, and no particular excellence can be ascribed to any one method. Each basis used has its particular fault. There are large yearly variations in runoff for the same rainfall. The carry-over from underground storage from one year to the next is a factor. Estimates of runoff based on a very small watershed are not directly comparable, because of differing climatic characteristics, to those of a complete larger watershed.

A comparison of the "Percent of mean annual discharge" of Mojave River (based on Finkle, Rowe, and Browning estimate) with that of the Santa Ana River (as measured by the United States Geological Survey) for the 20-year period 1902-03 to 1931-32 is given in Plate 2. For example, the mean annual discharges for the years of record are 68,200 acre-feet

TABLE 29. - Various estimates of annual discharge in acre-feet of the Mojave River below the Forks

Year	State Engineer 1/	Finkle, Rowe Browning 2/	Tait 3/	Arrowhead Corporation 4/	U. S. Geological Survey
1892-93	123,600	138,000			
1893-94	23,600	27,600			
1894-95	177,500	206,000			
1895-96	23,600	16,700			
1896-97	121,300	80,500			
1897-98	20,200	15,600	27,040		
1898-99	14,600	6,000	13,878		
1899-90	23,600	11,700	18,132		
1900-01	89,900	102,000	96,598		
1901-02	35,900	20,500	33,789		
1902-03	121,300	89,000	107,315		
1903-04	27,000	22,900	28,232		
1904-05	104,900 5/	104,846 5/	95,016		
1905-06	136,700 5/	133,778 5/	135,220	135,000	
1906-07	255,100 5/	255,321 5/	254,317	255,000	
1907-08	58,900 5/	60,396 5/	60,776	58,600	
1908-09	89,600 5/	96,046 5/	69,740	96,200	
1909-10	136,300 5/	182,012 5/	135,705	181,000	
1910-11	148,400 5/	146,431 5/	147,938	147,000	
1911-12	47,600 5/	45,628 5/	46,964	45,200	
1912-13	26,000 5/	25,682 5/	26,360	25,900	
1913-14	170,400 5/	154,060 5/	169,935	165,000	
1914-15	122,400 5/	135,863 5/	122,636	135,000	
1915-16	196,600	234,911 5/		234,000	
1916-17	68,500	55,508 5/		54,800	
1917-18	60,700	58,781 5/		58,700	
1918-19	42,700	15,307 5/		15,400	
1919-20	110,100	89,234 5/		89,400	
1920-21	73,000	51,048 5/		52,400	

(Table 29 continued on page 70.)

TABLE 29. - Contd.

Year	State Engineer 1/	Finkle, Rowe Browning 2/	Tait 3/	Arrowhead Corporation 4/	U. S. Geological Survey
1921-22		344,117 5/			
1922-23		145,000			
1923-24		43,500 6/			
1924-25		42,000			
1925-26		85,000			
1926-27		119,000			
1927-28		30,000			
1928-29		43,500			
1929-30		31,410			
1930-31		15,410			15,400
1931-32		99,101			99,300
1932-33					22,500
1933-34					16,100

1/ California State Division of Engineering and Irrigation Bulletin No. 5, "Flow in California Streams - Appendix A," 1923.

2/ Season July 1 to June 30.

3/ California State Department of Engineering Bulletin No. 5, "Report on the Utilization of Mojave River for Irrigation in Victor Valley, California," p. 72, 1918.

4/ California State Division of Water Resources Bulletin No. 47, "Mojave River Investigation," 1934. Season October 1 to September 30.

5/ Based on actual observations.

6/ Corrected.

for the Santa Ana at Mentone and 98,500 acre-feet for the Mojave at the Forks. In the water year[1] 1931-32 the diagram indicates the Mojave flowed just about its mean annual, i.e. 100 percent, while the Santa Ana flowed slightly less than its mean annual, about 95 percent.

After reviewing the data available the authors have reached the conclusion that the estimates made by the State Engineer's office are conservative; hence they are included in this report. The discharge records at the various gaging stations maintained by the Arrowhead Lake Corporation and the United States Geological Survey were used in estimating the average runoff for the 29-year period beginning 1905-06. Where the record covers more than 10 years these estimates are shown in Table 30.[2]

TABLE 30. - Estimated mean annual discharge at stream gaging stations maintained by Arrowhead Lake Corporation and United States Geological Survey in mountain headwaters of Mojave River

Station	Elevation above sea level	Length of record complete seasons	Estimated annual mean discharge for 29-year period beginning 1905-06
	Feet	Years	Acre-feet
Buck Creek above junction Crab Creek	5650	1	
Cedar Creek	5300	2	
Cox's Creek	5200	2	
Crab Creek above junction Buck Creek	5750	3	
Crab Creek below junction Buck Creek	5200	14	2,600
Deep Creek below Green Valley Creek	5350	17	15,700
Dry Creek	5500	3	
East Fork Mojave River	3000	20	57,000
Fern Creek	5350	2	
Grass Valley Creek	5100	16	2,600
Guernsey Creek	5150	2	
Holcomb Creek	5250	17	8,000
Hook's Creek	4950	3	
Huston Flat Creek	4400	3	
Little Bear Creek	4950	13	8,400
Mill Creek	5000	0	
Midway Creek	5100	2	
Mojave River below Forks	3000	19	90,300
Pine Creek	5250	2	
Rock Camp Creek	4900	3	
Rocky Gulch	4900	3	
Saddle Creek	4900	1	
Shake Creek	5400	2	
Sheep Creek	5200	2	
West Fork Mojave River	3000	19	33,300

1/ The Geological Survey year is October to September, inclusive. The year adopted by Finkle, Rowe, and Browning is July to June, inclusive.
2/ State Bulletin No. 47.

Stream Gaging Stations in Valley Area

In addition to those in the mountain headwaters maintained by the Arrowhead Lake Corporation, the following permanent stations have been maintained in the valley:

East Fork at Mouth
- Arrowhead Lake Corporation: Dec., 1904 to Sept., 1922, inc.
- U. S. Geological Survey: Jan., 1930 to date.

West Fork at Mouth
- Arrowhead Lake Corporation: Dec., 1904 to June, 1922, inc.
- U. S. Geological Survey: Feb., 1930 to date.

Mojave River at Upper Narrows (Victorville)
- U. S. Geological Survey: Mar., 1899 to Dec., 1906, inc.
  Dec., 1930 to date.

Mojave River at Lower Narrows
- Arrowhead Lake Corporation: Dec., 1904 to Sept., 1915, inc.

Mojave River at Point of Rocks
- Arrowhead Lake Corporation: Dec., 1908 to June, 1911, inc.

Mojave River at Hodge
- U. S. Geological Survey: Oct., 1930 to Sept., 1932, inc.

Mojave River at Barstow
- U. S. Geological Survey: Oct., 1930 to date.

Mojave River at Afton
- U. S. Geological Survey: Jan., 1930 to Sept., 1932, inc.

Besides measurements made at these regularly maintained gaging stations, measurements were made by the United States Geological Survey on the same day once each week during 1931-32 when flood waters were not in the stream at Upper Narrows gaging station, Lower Narrows, Bryman, Helendale (just above Point of Rocks), Wild and Hodge gaging station. A few measurements were made at some of these points and at other points prior and subsequent to 1932. Those of 1931-32 are used herein because of being most complete.

Complete daily and monthly records of discharges at stations and results of the isolated measurements are found in the Water Supply Papers of the United States Geological Survey. The monthly records of the Geological Survey and the Arrowhead Lake Corporation as published in Bulletin No. 47 are included in this report as Tables 31 to 38, inclusive. The daily records of Arrowhead Lake Corporation are contained in a mimeographed publication of the State Division of Water Resources. These and the monthly records were calculated by the Division of Water Resources from original data furnished by the Corporation.

TABLE 31. - Monthly discharge, in acre-feet, of EAST FORK OF MOJAVE RIVER (Deep Creek) above junction with West Fork
All records from Arrowhead Company except seasons marked with * which are from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1904-05	--	--	155	1910	13900	22100	6220	8780	1910	465	81.6	46.5	--
1905-06	96.7	465	680	2700	3230	53800	14200	7880	3660	1170	410	221	88500
1906-07	275	1140	9000	14100	21100	49700	26400	9420	3720	1440	703	510	138000
1907-08	1300	1300	1210	5830	8330	9240	6230	3360	1260	417	258	197	38900
1908-09	484	596	1310	11300	15700	8790	12100	4650	1360	490	269	263	57300
1909-10	340	1320	31000	70600	6090	5800	7800	5440	544	183	107	118	129000
1910-11	240	464	606	16000	12600	43000	7800	3520	1640	802	219	136	87000
1911-12	502	713	1190	923	726	7540	8590	5100	1080	399	88.5	59.8	26900
1912-13	185	280	415	689	1930	3680	5430	1120	326	137	493	136	14800
1913-14	79.2	945	701	20700	39700	16200	8630	8430	2890	1210	116	71.5	99700
1914-15	247	295	1220	5280	30800	17000	14800	15200	3950	700	133	102	89700
1915-16	144	439	870	82400	25200	30000	8110	5010	1690	599	275	155	155000
1916-17	1560	817	996	2050	5580	8380	8650	3580	798	95.0	88.8	44.6	32600
1917-18	67.5	162	268	393	2820	32200	3120	1480	561	75.5	37.2	37.8	41200
1918-19	142	440	803	619	1120	3340	4130	789	91.5	36.4	22.6	42.0	11600
1919-20	196	435	1690	689	11700	16100	16600	5260	1160	214	31.3	22.0	54100
1920-21	258	676	606	3390	2910	9600	3620	6800	1790	243	37.6	29.9	30000
1921-22	214	101	51800	21900	44100	17900	21900	13800	3980	768	319	124	177000
1922-29	--	--	--	--	--	--	--	--	--	--	--	--	--
*1929-30	--	--	--	990	1470	6700	4140	6950	827	78.7	49.2	30.9	--
*1930-31	218	893	573	615	3600	1020	3790	1260	234	59.0	44.3	35.7	12300
*1931-32	138	418	3410	1430	28500	14700	11200	5800	1310	198	25.9	13.7	67100
*1932-33	187	308	652	1100	1610	5120	3420	1590	446	19.9	8.1	6.0	14500
*1933-34	14.3	131	2330	5880	1260	1320	446	146	99.4	14.3	20.8	25.8	11700
**1934-35	1480	397	3650	5370	8260	4750	11500						

** Provisional U. S. Geological Survey records.

TABLE 32. - Monthly discharge, in acre-feet, of WEST FORK OF MOJAVE RIVER above junction with East Fork
All records from Arrowhead Company except seasons marked with * which are from U.S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1904-05	--	--	1.2	240	6670	34200	3500	4470	555	8.7	0	0	--
1905-06	0	2.3	2.6	932	1220	29200	7540	4880	2750	219	3.4	1.7	46700
1906-07	2.1	4.4	8120	23100	15800	52300	12800	4150	1430	42.9	6.0	2.3	118000
1907-08	4.9	6.7	98.7	4930	7930	3690	1650	1300	48.3	4.9	1.5	0	19700
1908-09	2.0	2.5	4.8	7220	17800	6750	5290	1560	235	4.8	2.7	2.2	38900
1909-10	3.0	125	12500	31800	3600	2120	1890	351	8.3	6.1	3.7	2.2	52400
1910-11	3.5	3.4	3.2	7170	13000	32300	5010	2160	478	21.2	6.4	4.7	60200
1911-12	6.0	5.1	134	246	77.0	8990	6890	1620	77.7	6.0	3.8	2.8	18100
1912-13	3.0	3.5	2.7	210	5140	3780	1580	358	29.3	5.3	5.0	3.1	11100
1913-14	2.2	3.1	3.0	13500	36300	7560	3790	3030	752	12.8	5.8	3.4	65000
1914-15	2.8	2.7	461	6300	22200	6480	3210	6060	860	10.3	5.9	4.6	45600
1915-16	7.6	19.0	40.0	46100	14100	13400	4370	1690	260	11.0	3.9	2.6	80000
1916-17	3.3	105	731	1820	8120	5510	3600	1770	461	5.4	2.1	1.4	22100
1917-18	2.2	2.5	2.8	3.2	- 942	14600	1390	460	89.2	4.6	1.1	0	17500
1918-19	1.7	1.6	60.6	118	910	1800	821	122	7.1	2.0	0	0	3840
1919-20	0.4	2.0	817	235	5810	17200	8340	2310	554	6.0	2.6	0.8	35300
1920-21	1.3	2.5	129	3570	1730	6590	1410	6500	1130	14.3	2.7	0	21100
1921-29	--	--	--	--	--	--	--	--	--	--	--	--	--
*1929-30	--	--	--	--	123	4180	1080	3780	114	0	0	0	--
*1930-31	0	0	3.6	97.2	1160	43.0	1550	235	0	0	0	0	3090
*1931-32	0	0.4	2000	1440	20400	5980	1650	611	57.7	0	0	0	32100
*1932-33	0	0	0	1400	1340	3450	1240	526	4.8	0	0	0	7960
*1933-34	0	0	329	3480	361	240	15.9	0	0	0	0	0	4430
**1934-35	79	0	785	4340	3880	2790	4630						

** Provisional U.S. Geological Survey Records.

TABLE 33. - Monthly discharge, in acre-feet, of MOJAVE RIVER below Forks
All records from Arrowhead Company except seasons marked with * which are from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1904-05	--	--	156	2150	20500	56300	9710	13300	2460	474	81.9	46.6	--
1905-06	100	467	682	3640	4440	82600	21800	12800	6410	1380	414	221	135000
1906-07	284	1140	17100	37200	36900	102000	39200	13600	5190	1480	709	512	255000
1907-08	1300	1300	1310	10800	16300	12900	7880	4650	1310	422	259	197	58600
1908-09	486	597	1310	18500	33600	15500	17400	6200	1600	495	271	264	96200
1909-10	344	1440	43500	102000	9690	7910	9720	5790	552	189	113	119	181000
1910-11	244	468	609	23100	25600	75400	12800	5690	2130	822	225	142	147000
1911-12	509	719	1320	1170	804	16500	15700	6720	1160	406	93.2	61.9	45200
1912-13	187	284	416	894	7060	7450	7020	1480	355	143	499	140	25900
1913-14	79.5	947	704	34200	76000	23700	12400	11500	3640	1220	123	75.6	165000
1914-15	248	297	1680	11600	53000	23500	18000	21300	4810	710	139	108	135000
1915-16	152	458	910	128000	39300	43400	12500	6700	1950	610	280	157	234000
1916-17	1560	921	1730	3870	13700	13900	12200	5340	1360	100	89.6	44.8	54800
1917-18	67.6	163	270	395	3760	46800	4510	1940	652	79.7	37.5	37.9	58700
1918-19	143	440	864	737	2030	5130	4950	912	98.7	38.1	22.6	42.0	15400
1919-20	196	436	2530	924	17600	33200	24900	7570	1720	220	33.9	22.8	89400
1920-21	259	678	736	6970	4640	16200	5030	13300	4240	257	40.7	30.1	52400
1921-29	--	--	--	--	--	--	--	--	--	--	--	--	--
*1929-30	--	--	--	--	1590	10900	5220	10700	941	78.7	49.2	30.9	--
*1930-31	218	893	577	712	4760	1060	5340	1500	234	59.0	44.3	35.7	15400
*1931-32	138	418	5410	2870	48900	20700	12800	6410	1370	198	25.9	13.7	99300
*1932-33	187	308	652	2500	3000	8570	4660	2120	452	19.9	8.1	6.0	22500
*1933-34	14.3	131	2660	9360	1620	1560	462	146	99.4	14.3	20.8	25.8	16100
**1934-35	1559	397	4435	9710	12140	7540	16130						

** Provisional U.S.G.S. records.

Note:- This table is a combination of Tables 31 and 32.

TABLE 34. - Monthly discharge, in acre-feet, of MOJAVE RIVER at Victorville
All records from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1898-99	--	--	--	--	--	2270	2200	2030	1730	1660	1480	1310	--
1899-00	1410	1610	1720	2700	2720	3510	2080	2030	1790	1600	1780	1730	24700
1900-01	1970	8270	2030	11300	51400	10900	2620	3010	2500	2460	3070	3270	103000
1901-02	4240	4580	4490	3070	3330	4060	3510	2640	2980	2460	2460	2620	40400
1902-03	2890	2740	4000	3500	3500	30900	45500	4920	2320	2270	2400	2440	107000
1903-04	3200	3270	3570	3690	3280	3570	2680	2890	2260	2030	2150	2020	34600
1904-05	2950	2970	3630	3700	17200	42700	6540	8980	2580	1990	1940	2380	97600
1905-06	2860	3810	4120	--	--	--	--	--	--	--	--	--	--
1906-30	--	--	--	--	--	--	--	--	--	--	--	--	--
1930-31	--	--	2120	2350	2230	2090	2040	1750	1370	1270	1300	1650	--
1931-32	1930	1960	2460	2430	40600	17000	9160	3010	1670	1320	1250	1450	84200
1932-33	1840	2140	2520	2920	2370	2400	2140	2020	1510	1380	1210	1480	23900
1933-34	1820	2170	2420	4390	2200	2180	1810	1690	1540	1210	1110	1290	23800
*1934-35	2000	1950	2200	2510	5430	2180	9740						

* Provisional.

TABLE 35. - Monthly discharge, in acre feet, of MOJAVE RIVER at Lower Narrows
All records from Arrowhead Company

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1904-05	--	--	2830	2550	6060	35500	5130	7070	1540	1320	1590	1660	--
1905-06	2380	2770	2840	2890	2490	56300	17700	8170	3120	1420	1480	1900	103000
1906-07	2280	2580	9280	30800	37100	64900	39000	8520	2410	1410	1590	1860	202000
1907-08	2640	2680	2800	6140	11600	8940	4330	2510	1700	1700	1720	2050	48800
1908-09	2420	2460	2720	14000	31400	12600	15300	3190	1690	1480	1640	1780	90700
1909-10	2320	2960	25300	74300	7660	5790	7440	3900	2010	2080	1920	2160	138000
1910-11	2890	3120	3280	13600	23400	64200	9370	2590	1790	1840	1870	2220	130000
1911-12	3100	3260	3420	3420	3040	8890	11100	3860	1850	1960	1560	1820	47300
1912-13	3000	2980	3350	3350	3170	2840	2600	2160	2180	1860	1930	1900	31300
1913-14	2720	3030	3290	34000	68600	22200	9170	8640	2140	1890	1820	2150	160000
1914-15	2740	3070	3470	14000	51500	24100	17300	19900	3340	1860	1790	2260	145000

TABLE 36. - Monthly discharge, in acre-feet, of MOJAVE RIVER near HODGE
All records from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1930-31	0	0	0	347	1210	608	151	0.6	0	0	0	0	2320
1931-32	0	0	331	1190	32400	15700	8270	1600	0	0	0	0	59500

TABLE 37. - Monthly discharge, in acre-feet, of MOJAVE RIVER at BARSTOW
All records from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1930-31	0	0	0	0	0	0	0	0	0	0	0	0	0
1931-32	0	0	0	0	26300	9960	3940	105	0	0	0	0	40300
1932-33	0	0	0	0	0	0	0	0	0	0	0	0	0
1933-34	0	0	0	0	0	0	0	0	0	0	0	0	0
*1934-35	0	0	0	0	0	0	1180						

*Provisional.

TABLE 38. - Monthly discharge, in acre-feet, of MOJAVE RIVER at AFTON
All records from U. S. Geological Survey

Season	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1929-30	--	--	--	116	92.8	102	78.6	81.8	56.5	38.7	36.9	51.8	--
1930-31	86.1	102	113	118	108	117	122	111	85.7	64.6	49.8	45.2	1120
1931-32	73.2	114	121	129	6500	701	115	67.0	31.7	13.5	15.9	28.0	7910

The West Fork and East Fork stations do not measure the entire mountain runoff as there are diversions above the West Fork station for irrigation in the mountain valleys and the diversion for the conduit leading to Hesperia above the East Fork station. Arrowhead Lake also loses water by evaporation and there is some irrigation around it. Prior to its development the floor of the lake was of a swampy nature so that evaporation from the lake is not entirely a new draft on the stream. When the recorded discharges of the two forks are added, the discharge of Mojave River at the mountain toe is the result. The estimates of mountain runoff herein used are from the recorded discharge.

All these various records are useful in determining percolation in various areas, rising water at various points, consumptive use of the cultivated and natural vegetation along the river. The record at Afton gives the final waste past which any use of water for a general development is not possible.

Water Losses

Forks to Upper Narrows. - The stream flow at the Forks in normal years is lowest during the late summer and early fall months. When cool weather comes, the evapo-transpiration losses are less because of decreased temperatures and defoliation of the native vegetation, and the stream flow gradually increases. This stream flow is also augmented by light autumn rains. As this flow passes the Forks, it is absorbed in the porous stream bed where it percolates downward to the underground water table and gradually replenishes the basin. As this basin is replenished, the water table rises until the basin is filled and the surface stream gradually increases in length below the Forks until usually it extends some two miles below the Forks before the winter floods begin.

A very large proportion of the first flood flows is absorbed in the stream bed and a flow of over 500 second-feet at the Forks is needed for the surface flow to extend to the point of rising water above the Narrows. Even in the driest years the maximum depth to water at the upper end of the basin never exceeds 50 feet and gradually lessens as the point of rising water is approached downstream. The first floods that occur lose a portion of their flow by a direct downward percolation of water, which, of course, is at the maximum rate of percolation. As soon as the water table in the basin is sufficiently elevated to come in contact with the surface stream, the rate of percolation diminishes.

During the investigation by the State Division of Water Resources the water table stood at about 40 feet below the stream bed at a distance of five miles below the Forks. After the flood of 1932 it had risen 25 feet, but fell 20 feet during the succeeding summer. From this point the depth gradually decreases upstream to the Forks and downstream to a distance of about four miles above Upper Narrows where the water table intercepts the surface. Trees evidencing high water table are found in the river bottom extending six miles above the Upper Narrows.

Discharge records show the loss in this section of the river. If this were corrected for change in underground storage the result would be the consumptive use.

TABLE 39. - Loss from the Forks to Upper Narrows

Period[1]	Discharge at Forks	Discharge at Upper Narrows	Loss or gain
	Acre-feet	Acre-feet	Acre-feet
1904-05	105,300[2]	97,600	7,700 loss
1930-31	15,400	21,700[2]	6,300 gain
1931-32	99,300	84,200	15,100 loss
1932-33	22,500	23,900	1,400 gain
1933-34	16,100	23,800	7,700 gain
1934-35[3]	51,900	26,000	25,900 loss[3]

1/ October to September, inclusive.
2/ October and November estimated.
3/ October to April, inclusive.

Table 39 indicates a regimen typical of such underground basins. In the approximately normal years such as 1931-32 and 1904-05 following years of small run-off, the outflow is less than the recharge; and in low years the reverse is true. For the period October, 1930 to April, 1935, inclusive, the average annual loss is 5,100 acre-feet. This amount undoubtedly would be less if the summer record for 1935 were available for inclusion in the average, as the rising water at the Upper Narrows during the summer months (when the flow at the Forks is usually low) will change the results. In addition to the surface outflow measured at the Narrows there is draft caused by the consumptive use of vegetation, evaporation from the stream surface, and underflow. The latter is estimated by Slichter to be five-tenths second-foot.

Upper Narrows to Lower Narrows. - The stream flows in a broad canyon-like valley in this section. Bottom lands support a heavy growth of trees and there is some irrigation. Springs appear along the west canyon wall but have not been measured. This flow is from the underground water resulting from percolation from minor streams west of Mojave River, probably to Sheep Creek. The increment can be estimated by the measurements made on the river flow in the dormant season when transpiration losses do not mask the inflow.

The difference between the gain from springs and under-seepage and the average loss for the year represents transpiration and evaporation loss. This has been estimated (in State Bulletin No. 47) as a total of about 3,000 acre-feet.

Upper Narrows to Hodge. - Below the Upper Narrows the river flows in a narrow section to Hodge. Even during the driest years when no flow from the Forks reaches Victorville as surface flow, the rising water at the Upper Narrows is sufficient to recharge the basin to Hodge. The difference between discharges at gaging stations maintained by the United States Geological Survey at Upper Narrows (Victorville) and Hodge, for 1930-31 and 1931-32, is shown in Table 40.

TABLE 40. - Difference in flow Upper Narrows and Hodge

Year	Upper Narrows	Hodge	Difference
	Acre-feet	Acre-feet	Acre-feet
1930-31	21,700 1/	2,320	- 19,400
1931-32	84,200	59,500	- 24,700

1/ Small flows in October and November estimated.

By estimating the flow at Hodge for other years, the difference in flow between Victorville and Hodge from 1929-30 to 1933-34 will average about 20,000 acre-feet per year.

Hodge to Barstow. - Below Hodge the river passes over a broad absorption area before reaching Barstow. The loss between Hodge and Barstow represents absorption into the underground water basin supplying the Hinkley Valley and areas along the river above Barstow. The loss, for 1930-31 and 1931-32, between gaging stations maintained at Hodge and at Barstow by the United States Geological Survey is shown in Table 41.

TABLE 41. - Loss of water, Hodge to Barstow

Year	Hodge	Barstow	Loss
	Acre-feet	Acre-feet	Acre-feet
1930-31	2,320	0	2,320
1931-32	59,500	40,300	19,200

The loss is almost all percolation into the stream bed. The water table at the deepest point, about nine miles above Barstow, was 25 feet below the surface. Actual loss in the year is greater than that shown in the table for 1930-31 and less for 1931-32, as storage in the basin decreased in 1930-31 and increased in 1931-32.

If the water table in this area were lowered to a greater depth it would produce a larger absorptive capacity since a very large flood is not required to raise the water table to a point of contact with a surface stream, thus decreasing the absorption losses.

Barstow to Afton. - At Afton there is always a small flow caused by the overflow from the basin above it and below Forks-of-the-Road Fault. In 1931-32 a surface stream forced its way from Barstow to Afton. During that year the stream flowed at Barstow from February 9 to May 10, inclusive, giving a total discharge of 40,300 acre-feet. The flood water ceased to flow at Afton about March 8, and the discharge of flood water during that period, after deduction of normal rising water, is estimated at 7,000 acre-feet. Of this, about 1,000 acre-feet was evidently from a local storm, as the discharge at Afton rose from 16 second-feet on February 16 to 274 second-feet on February 18, with a rise of only 68 second-feet at Barstow.

Forks to Afton. - During the period October, 1931 to September, 1932, inclusive, the United States Geological Survey made complete measurements of the Mojave at various stations along the river. Most of these records are summarized by months in Table 42, which indicates the amount of absorption in the different basins from the Forks to Afton. However, in analyzing these results it should be remembered that the year 1931-32 was preceded by a series of dry years. After a series of wet years the apparent loss in some basins would have been less. Conkling and Gleason comment on the losses between the Forks and Afton as follows:[1]

"The total discharge from the mountains plus increments below minus flow at Afton gives the loss each year. As the only record of flood flow past Afton is in 1931-32, that year's record is the only one indicative of the total loss in the stream system. Increments other than springs from Upper Narrows to Bryman are probably negligible.

"Loss of Water Mountains to Afton 1931-32

	Acre-feet	Acre-feet
Inflow		
Discharge at Forks	99,300	
Inflow from springs	7,000	
Flood originating below mountains..	1,000	107,300
Discharge at Afton		7,900
Transpired, evaporated or stored underground		99,400

"Using round figures it may be said that 100,000 acre-feet was lost by evaporation and transpiration or stored underground in 1931-32. This is the same as the discharge in that year from the mountain headwaters.

"The water stored was not lost during that year although it may be lost in subsequent years. The loss or use is the water evaporated and transpired by the native vegetation in areas of high water table, by the irrigated land and by the towns and railroads. The water table was slightly higher in the fall of 1932 than in the fall of 1931 and thus permanent or over year storage took place. If several wet seasons occurred in succession the water table would gradually rise above the level of fall, 1932, to a point where rising water outflows would balance the input. The water table slopes away from the river to the north

1/ State Bulletin No. 47, p. 60.

TABLE 42. - Water losses, Mojave River, Forks to Afton, in acre-feet, October, 1931 to September, 1932 1/

Item	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total Loss
Discharge, Below Forks 2/	138	418	5410	2870	48900	20680	12850	6411	1367.7	198	25.9	13.7	
Victorville	1930	1960	2460	2430	40600	17000	9160	3010	1670	1320	1250	1450	
Loss - Forks to Victorville	1792 3/	1542 3/	2950	440	8300	3680	3690	3401	302.3 3/	1122 3/	1224.1 3/	1436.3 3/	15042
Discharge, Hodge	0	0	331	1190	32400	15700	8270	1600	0	0	0	0	
Loss - Victorville to Hodge	1930	1960	2129	1240	8200	1300	890	1410	1670	1320	1250	1450	24749
Discharge, Barstow	0	0	0	0	26300	9960	3940	105	0	0	0	0	
Loss - Hodge to Barstow	0	0	331	1190	6100	5740	4330	1495	0	0	0	0	19186
Discharge, Afton	73.2	114	121	129	6500	701	115	67	31.7	13.5	15.9	28	
Loss - Barstow to Afton	73.2 3/	114 3/	121 3/	129 3/	19800	9259	3825	38	31.7 3/	13.5 3/	15.9 3/	2.8 3/	32421

1/ Based on discharge records in U. S. Geological Survey W. S. Paper 735.
2/ Combined discharge of Deep Creek and West Fork.
3/ Gain.

below Hodge and to the northeast below Daggett and it is conceivable that the additional rising water might appear not only in the river but at points north of it, but no record of wet spots of magnitude to the north is found except Harper Lake to which underflow from Mojave River must be small, as the underground outlet to the lake is very constricted. Harper Lake was dry during the period of investigation. Below Forks-of-the Road Fault an ancient lake existed. Its exact boundary is not known but its western end is thought to have extended almost to the fault and the lake bed formation would militate against rapid underground flow from the river.

"Because the water table slopes away from the river and because there is such a large amount of native vegetation along the channel, both of which would lower the water table at the river during the growing season when the stream is dry, there would always be space after the growing season into which the floods could percolate. It is believed, however, if the discharge of 1931-32 had occurred after a series of wet years instead of a series of dry years, that because of the higher water table the apparent loss above Afton would have been less."

Underground Water

Several governmental agencies, the Arrowhead Lake Corporation, and consulting engineers have made well measurements in connection with underground water studies in Mojave Valley at various times. Most of these data are reproduced in the Appendix of State Bulletin No. 47. However, the authors were able to obtain later well records through the courtesy of the United States Geological Survey.

The Division of Irrigation, United States Department of Agriculture, in cooperation with the County of San Bernardino and State of California, in 1917 made a survey of wells and pumping plants of the Upper Mojave Valley to determine location, depth to water, and the extent to which pumping can be relied upon for the reclamation of the land. Levels were run to establish the elevation of the water in the wells and for the platting of hydrographic contours from which to make deductions concerning the slope and direction of movement of the underground water. The results are reported in detail in State Bulletin No. 5.

In 1916 and 1920 the United States Geological Survey collected data on wells in the Mojave River Basin. The records are published in Water Supply Paper 578. Since 1929 the Geological Survey, in cooperation with the State Division of Water Resources, has been making measurements of depth to water in wells throughout the valley. The results up to the year 1934 are reported in State Bulletin No. 47.

Water table. - Contours of the water table as of fall, 1930 are shown on Plates 5-A, 5-B, and 5-C in Appendix for the area in which elevations of ground surface or measuring point at the wells were secured during the investigation by the State Division of Water Resources. In addition, water table contours from the mountains north to Dry Lake and extending about 20 miles west of Victorville are shown on map in Bulletin 5, Department of Engineering, State of California.

"Under the mesa west of Victorville the water table slopes to the northeast and apparently there might be underflow into the river from the west from about four miles south of Victorville to Bryman, nine miles north of Victorville and even further. The water table continues to slope to the northeast but the river gradually swings to the east and about five miles above Barstow is flowing almost due east. For a distance above this the underground water is moving away from the river under the Hinkley Valley and is maintained by seepage from the river.

"From about five miles above Barstow the direction of movement of the underground water is the same as that of the river. At Barstow the stream turns to the southeast and at Daggett to the northeast, but the underflow continues practically straight east. Apparently water goes through the Forks-of-the Road Fault, and on the south side of the valley from Newberry to Dry Lake the slope is almost in the same direction as the Santa Fe Railroad. Below and near the fault, however, the slope is at right angles to the fault, probably because the underflow is dammed back by the fault but trickles through it into more porous material, as seems probable by the steep slope of the water table below the fault.

"For several miles below the fault the slope of the water table is at right angles to the fault but gradually the slope swings to the north and has a much more northerly direction than the stream.

"On the east side of the stream below where it enters the plains, and on the south in the vicinity of Barstow where the stream is flowing easterly, the water table slopes toward it. However, the watershed is small and the contribution is negligible below Victorville although possibly of sensible proportions for a short distance above.

"Area of influence of Mojave River. - The approximate estimated boundary is shown on key map (Plate I). The area included totals 333 square miles. The boundary is deduced from water table contours, geology, and topography. Presumably the constricted underground channels north of Hinkley Valley would restrict movement of water toward Harper Lake from Hinkley Valley so that even if greater pumping draft were made north of Hinkley Valley the amount of water passing out of it to the north would be small. The aquifers from the river to Hinkley Valley are apparently very porous.

"The formation conveying water from the river into and under the Newberry-Dry Lake area would not, it is believed, transmit water from the stream as freely as is possible to Hinkley Valley, and as the water reaching the Newberry-Dry Lake area from the river is that which has percolated to the south side below Barstow and above Forks-of-the Road Fault and must pass through the fault to reach the area, it is believed that its flow would be so impeded by the fault as to cause serious question whether a large amount could enter the area from that direction even were the water table lowered greatly in the area. Below the fault the lake bed formations which begin at some not definitely located point would also impede movement of water into the area from the river although it might freely enter below the fault to the point where the lake bed formation begins." 1/

1/ State Bulletin No. 47.

Fluctuations of water table. - The locations of wells in Mojave Valley are shown on Plates 5A, 5B, and 5C. Records of water levels in typical wells along the river are shown in Appendix Tables B to D. Comparison of water table elevation for any long period of time is rather difficult because of paucity of records. Large seasonal fluctuations in water table are found for many of the wells near the river due to percolation from the river when in flood and rapid equalization of the water table as the water near the river moves laterally away from it or drains out of the basin. The records indicate in general a recession since 1917, which would be expected since the runoff has been subnormal. Changes in water levels in typical wells in the Mojave Valley from the Forks to the lower part of the valley are shown in Table 43. For the most part these changes are based on winter records as the observations made in the spring and fall are too meager.

The maximum drop in water level in the Upper Mojave Valley is indicated to be just below the Forks. The water level in Well No. U-1 dropped 13.4 feet from January, 1923 to January, 1935, or 1.12 feet per year. However, from December, 1929 to January, 1935 there was a rise of 2.9 feet, or 0.48 foot per year. This well is apparently in the older alluvium which comprises the saddle at the West Fork damsite. The lowering was less in other localities, while in several instances the 1935 records indicate that there has been a rise in the water table in the past five years. Wells like No. U-13 which are located in the modern alluvium of the flood plain of Mojave River respond more quickly to flood flows than wells in the older alluvium.

The available records of wells indicate that there is no general lowering of the water table in the Middle Mojave Valley adjacent to the river. However, there has been a drop in Hinkley Valley ranging from about 0.2 foot to 0.9 foot per year, in recent years. Conkling and Gleason indicate that there has been a general recession of about five feet in this area from 1919 to 1931.

In the Lower Mojave Valley below Barstow the available records indicate that there has been a general recession of the water table in most sections, the greatest drop in water level being in the vicinity of Daggett.

TABLE 43. - Changes in water levels in typical wells in Mojave Valley

Location	Well number	Month	Year	Depth to water 1/	Month	Year	Depth to water 1/	Drop in water level: Total	Drop in water level: Yearly
				Feet			Feet	Feet	Feet
				Upper Mojave Valley					
1 mi. below Forks	U- 1	Jan.	1923	68.6	Jan.	1935	82.0	13.4	1.12
		Dec.	1929	84.9	Jan.	1935	82.0	2.9 2/	0.48 2/
4½ mi. below Forks	U- 9	Mar.	1917	32.8	Apr.	1935	39.2	6.4	0.36
		Jan.	1930	45.6	Jan.	1935	47.0	1.4	0.28
Hesperia Crossing (5 mi. below Forks)	U-13	Jan.	1905	39.6	Jan.	1935	38.5	1.1 2/	0.04 2/
		Mar.	1930	39.4	Jan.	1935	38.6	0.8 2/	0.16 2/
		May	1930	24.7	May	1935	17.0	7.7 2/	1.54 2/
6 mi. east Hesperia	U-17	Jan.	1930	255.7	Jan.	1935	258.6	2.9	0.58
		May	1931	256.6	May	1935	255.3	1.3 2/	0.33 2/
Verde Crossing (9 mi. below Forks)	U-72	Apr.	1917	4.0	May	1935	5.5	1.5	0.08
		Apr.	1930	6.6	May	1935	5.5	1.1 2/	0.22 2/
East of Verde Crossing	U-43	Feb.	1917	51.5	Jan.	1935	57.4	5.9	0.33
		Jan.	1930	56.3	Jan.	1935	57.4	1.1	0.22
3 mi. east Victorville (Mesa)	U-57	Feb.	1917	98.0	Feb.	1935	107.5	9.5	0.53
		Feb.	1923	104.2	Feb,	1935	107.5	3.3	0.28
		Jan.	1930	106.7	Feb.	1935	107.5	0.8	0.16
1 mi. east Victorville	U-59	May	1931	55.8	May	1935	55.4	0.4 2/	0.10 2/
				Middle Mojave Valley					
Oro Grande	M- 3	Dec.	1930	18.3	Jan.	1935	18.4	0.1	0.03
Southwest Helendale	M-15	Dec.	1930	15.0	Jan.	1935	15.0	0	0
Hodge	M-40	Jan.	1919	16.1	Jan.	1935	16.9	0.8	0.05
		Jan.	1930	16.5	Jan.	1935	16.9	0.4	0.08
2 mi. north Hodge	M-51	Feb.	1931	6.7	Feb.	1935	6.2	0.5 2/	0.13 2/
4 mi. north Hodge	M-52	Feb.	1931	91.4	Feb.	1935	91.5	0.1 2/	0.03 2/
3 mi. northeast Hodge	M-57A	Mar.	1931	18.5	Feb.	1935	19.1	0.6	0.15
		Mar.	1931	18.5	Apr.	1935	7.4	11.1 2/	2.78 2/
4 mi. northeast Hodge	M-56A	Mar.	1931	24.4	Apr.	1935	18.3	6.1 2/	1.53 2/
3 mi. northeast Hodge	M-57A	Mar.	1931	18.5	Feb.	1935	19.1	0.6	0.15
		Mar.	1931	18.5	Apr.	1935	7.4	11.1 2/	2.78 2/

(Table 43 is continued on page 87.)

TABLE 43 Continued.

Location	Well number	Month	Year	Depth to water 1/	Month	Year	Depth to water 1/	Drop in water level Total	Yearly
(Middle Mojave Valley - Contd.)				Feet			Feet	Feet	Feet
1½ mi. east Hinkley	M-71	Mar.	1932	28.0	Mar.	1935	30.7	2.7	0.90
4 mi. southeast Hinkley	M-74	Dec.	1930	20.8	Jan.	1935	21.6	0.8	0.20
4 mi. east Hinkley	M-75	Apr.	1930	63.2	Mar.	1935	66.2	3.0	0.60
4½ mi. north Hinkley	M-66	May	1930	29.5	Mar.	1935	30.5	1.0	0.20
Barstow	M-86	Dec.	1930	13.4	Jan.	1935	13.2	0.2 2/	0.05 2/
Lower Mojave Valley									
3 mi. southeast Barstow	M-92	May	1930	9.9	May	1935	10.9	1.0	0.20
2 mi. west Daggett	L- 1	May	1927	10.3	Apr.	1932	11.4	1.1	0.22
		Jan.	1930	29.6	Jan.	1935	29.9	0.3	0.05
		May	1930	30.8	May	1935	31.4	0.6	0.12
1 mi. east Daggett	L-42	Feb.	1927	74.2	Jan.	1935	79.2	5.0	0.62
		May	1930	75.2	May	1935	80.3	5.1	1.02
4 mi. east Daggett	L-63	Mar.	1926	50.3	Mar.	1932	58.5	8.2	1.36
		Jan.	1931	58.2	Jan.	1935	60.7	2.5	0.62
2 mi. northeast Minneola	L-68A	Feb.	1930	21.1	Feb.	1934	20.8	0.3 2/	0.08 2/
		Feb.	1930	21.1	Jan.	1935	21.5	0.4	0.08
2½ mi. northwest Newberry	L-16A	May	1922	Flowing	Apr.	1932	2.0	2.0	0.20
		Jan.	1931	1.8	Jan.	1935	3.6	1.8	0.45
Northeast Newberry	L-19	May	1922	29.2	Apr.	1932	28.5	0.7 2/	0.07 2/
		Feb.	1930	28.2	Jan.	1935	29.4	1.2	0.24
Southeast of Newberry	L-20	Apr.	1930	Flowing	Jan.	1935	Flowing	--	--
4 mi. east Yermo (above Fault)	L-52	Feb.	1930	5.5	Jan.	1935	6.7	1.2	0.24
		May	1930	6.3	Apr.	1932	6.2	0.1 2/	0.05 2/
4 mi. east Yermo (below Fault)	L-51	Jan.	1931	19.0	Jan.	1935	21.9	2.9	0.71
		May	1930	16.5	Apr.	1932	16.7	0.2	0.10
2½ mi. south Harvard	L-78	Mar.	1930	8.2	Jan.	1935	9.1	0.9	0.18

1/ Below reference point.
2/ Rise.

To be considered in any plan of development involving Mojave River, whether in its own valley or elsewhere, are both the surface and subsurface water supplies, their present uses, and the possibilities of their improvement and extension.

Surface Water Supply of Mojave River

The average annual discharge of the Mojave River from the mountains through the main river and the increment from ground-water flow below Victorville in the 29-year period beginning 1905 are together estimated by Conkling and Gleason to approximate 97,000 acre-feet. During the period of rainfall records, which started in the mountains in 1883-84, there have been periods of 10 and 12 years of very subnormal rainfall during which the run-off from the mountains averaged a little more than 50 percent of the 29-year average.

The estimated water supply of the river for different periods in the past is shown in Table 44. 1/

TABLE 44. - Average annual water estimated to have been available in Mojave River

Period	Years	Mountain discharge	Inflow from springs 1/	Total
		Acre-feet	Acre-feet	Acre-feet
1883-84 to 1894-95	12	219,000	7,000	226,000
1895-96 to 1904-05	10	42,000	7,000	49,000
1905-06 to 1921-22	17	122,000	7,000	129,000
1922-23 to 1933-34	12	46,000	7,000	53,000
1905-06 to 1933-34	29	90,000	7,000	97,000

1/ The estimate for 1931-32 is used for all periods as the distance from the area where these waters get underground to the river is considerable and cyclic variations would be more or less obliterated.

Consumptive Use of Water

The inflow of water into any particular area under consideration is disposed of by domestic and industrial uses, by evaporation, by consumptive use (evapo-transpiration) of agricultural crops and native vegetation, by storage underground, and by flow out of the area.

1/ State Bulletin No. 47.

Domestic and industrial. - The consumptive use for the towns, railroads, and industries has been roughly estimated by Conkling as 1,100 acre-feet per annum,[1] divided as follows: Forks to Barstow 400 acre-feet; Barstow to Afton 700 acre-feet.

Agricultural crops. - It is believed that about 90 percent of the area now irrigated is in alfalfa, with the remainder in orchard, vegetables, and field crops. The State Division of Water Resources estimated that in 1929 about 80 percent of the cropped area was in alfalfa. The aerial survey made at that time indicated that there were 6,019 acres of irrigated land drawing water from the Mojave River below the Forks, either by gravity diversion and pumping along the river bottoms, or by pumping in Hinkley Valley to which water from the river moves underground. This does not include lands irrigated around Hesperia by gravity diversion above the Forks or the area away from the river around Adelanto supplied by pumping. The United States Census of 1935 shows 6,533 acres of irrigated land, for Mojave Valley townships (see Table 10). However, this figure includes Adelanto, Lucerne Valley, and other scattered areas. It is believed that 6,000 acres is a conservatively estimated area of irrigated land dependent upon Mojave River.

A spot survey by the authors indicated that from 6 to 9 acre-feet of water per acre per year are applied to alfalfa lands, or an average of about 7.5 acre-feet. Assuming an irrigation efficiency of 50 percent, 3.75 acre-feet would be available for crop use, while the remainder would return to the underground water supply. However, the consumptive use for other crops would be less, since smaller amounts of water are applied to them; hence it is believed that the average annual consumptive use by agricultural crops now being irrigated will not exceed 3 acre-feet per acre. This value is used in estimating the consumptive use of water in various areas as shown in Table 45.

TABLE 45. - Estimated area irrigated and use of water in Mojave Valley dependent on Mojave River

Area	Area irrigated[1]	Amount applied	Maximum consumptive use
	Acres	Acre-feet	Acre-feet
Forks to Victorville (Upper Narrows)	1,250	7,500	3,750
Victorville to Hodge	1,850	11,100	5,550
Hodge to Barstow[2]	1,800	10,800	5,400
Barstow to Afton	1,100	6,600	3,300
Total	6,000	36,000	18,000

1/ Estimated from United States Census of 1935 and State Survey of 1929. Lucerne Valley and scattered areas away from river are not included.
2/ Including Hinkley Valley.

1/ State Bulletin No. 47.

Referring again to the area distribution shown by the 1935 Federal Census, Table 10 indicates that there is 17,000 acres of land available for crops in farms now being operated along the Mojave River and in outlying sections. The authors assume that this includes the areas irrigated in 1934.

It is estimated somewhat arbitrarily that about 15,000 acres of the total 17,000 acres, if irrigated at all, would be dependent upon the river for a water supply, or more than 9,000 acres in excess of the present irrigated total.

Further examination of the table shows, however, that the "available" acreage (above the present) is more or less approximately the "idle or fallow" crop land. More than half of this surplus is shown for Victor township, while most of the remainder is in Oro Grande and Barstow townships. The combined surplus in the two latter townships is slightly less than the area irrigated and cropped in 1934, while the Victor township surplus is nearly three times the cropped area.

Supporting their field inspection of the valley with a close examination of the aerial photographs upon which the Appendix maps were based, the authors have considered the probability that these surplus acreages will actually be brought into the area of "crops harvested." The prospect as regards Oro Grande and Barstow townships appears entirely possible if economic conditions generally affecting the valley should show substantial improvement. In other words, surplus areas of that total extent having soil of fair quality appear to exist in the farms now operated, without consideration of areas not farmed at present.

With regard to Victor township, however, the situation is somewhat different. This township includes much of the Apple Valley area in which the early orchard development already described took place, and it appears likely that a substantial proportion of the area listed as "idle or fallow" is land that has been cropped but is now idle because of excessive pumping lifts or other present insupportable economic burdens. Much of it might come back into crops of one sort or another in some extensive development involving gravity distribution of water, but its return to production by individual effort is certainly not in early prospect. The authors consider that here, as in the sections lower downstream, a doubling of the cropped area of farms now operated may reasonably be anticipated, but not its doubling twice over.

Therefore, assuming that 6,000 acres of the "idle or fallow" land might be expected to have or acquire the position of a legitimate claimant to water, and that the net consumptive use would be as shown in Table 45, the amount of water demanded by the present farms would be double that now used unless more efficient irrigation practice should become general. As to the latter possibility the authors refer again to the discussion under the heading "Water Requirements of Irrigated Crops" and reiterate their opinion that a more economical application duty is possible and should be attained. The figures (in Table 45) for consumptive use likewise might be lowered, although not proportionately. The estimates shown are admittedly conservative, but in the absence of definitely determined allowances,

the authors are unwilling to compute probable future water consumption on any other basis.

Native vegetation. - Along the Mojave River there are moist areas where the noneconomic use of water by natural vegetation is considerable. In areas of high water table native vegetation is growing luxuriantly. A study by the Bureau of Agricultural Engineering at Victorville from 1931 to 1933 indicated that the mean annual loss from a tule tank which replicated swamp conditions was 78.45 inches.1/ The mean annual evaporation from a lake surface was estimated as 58 inches. The mean annual consumptive use for the entire moist area would undoubtedly be appreciably less than the value of 78 acre-inches per acre per year determined for the tule swamp areas. Investigations in Santa Ana Basin indicated that willows consume around 48 inches of water annually. A study in 1929 by the State disclosed that 7,800 acres of tules, willows, cottonwoods, etc., were growing along the river from the Forks to Cady Mountain.2/ Probably more than twice as much water is being consumed thereby as by all the domestic, industrial, and agricultural uses in the valley. However, the average annual use of water by native vegetation along Mojave River probably will not exceed 5 acre-feet per acre. Using this value, it is estimated that the use of water by native vegetation growing in moist areas is around 39,000 acre-feet per year.

No attempt has been made by the authors to estimate the area of native vegetation growing in different sections of the valley. However, Conkling has estimated the total consumption above Victorville Narrows for all purposes to be 13,000 acre-feet based on United States Geological Survey stream-flow records for 1932-33 and 1933-34. Estimates based on earlier records give a little lower value. Assuming 11,000 acre-feet as a fair approximation, subtraction of the agricultural and domestic use from the total consumption indicates that the use of water by native vegetation in the Upper Mojave Valley (between the Forks and Victorville) is around 7,000 acre-feet. This leaves 32,000 acre-feet of consumptive use below Victorville to be divided between the Middle and Lower Mojave valleys. Conkling has estimated the non-beneficial consumption in the Lower Valley from Barstow to Afton as 14,000 acre-feet. Using this as a basis, it is estimated that the use by native vegetation in the Middle Valley from Victorville to Barstow would be 18,000 acre-feet annually.

Surface Reservoirs

Possible reservoirs on the Mojave River except that immediately above Victorville are in the mountain headwaters. Their locations are shown on Plate I and on Plate 5-A in Appendix. Descriptions follow:

Victor reservoir site. - The dam site is in solid granite. It was drilled in 1899 by the United States Geological Survey.3/ Maximum

---

1/ California State Department of Public Works, Division of Water Resources, Bulletin No. 44, "Water Losses Under Natural Conditions from Wet Areas in Southern California, 1933," by Harry F. Blaney, Colin A. Taylor, A. A. Young, and Harry G. Nickle, 1933.

2/ State Bulletin No. 47.

3/ Eighteenth and Twenty-first Annual Reports of the United States Geological Survey.

depth to bedrock is 46 feet. The gorge is 140 feet wide at stream bed and at 145 feet above the stream is 350 feet wide. A considerable portion of the site is moist land caused by the rising water from the Victor Basin. Of the area beneath the highest flow line 760 acres were in crop in 1929. A little over two miles of the main line of the Santa Fe Railroad passes through the lower end.

Forks reservoir site. - This is situated on West Fork just above the Forks. The site lies along the contact of the valley alluvium with the granites of the mountains. The stream has cut its way through a spur from the mountains and this forms the dam site. Tait states in Bulletin 5:

".......... It was the original plan of the Mojave River Irrigation District to acquire and develop this site to impound the flood discharge of the West Fork and to store, by diversion, that in the lower part of the East Fork and to convey the water by gravity to the east mesa. The district, however, did not make known definite design, if any was decided upon, for the improvement of the site.

"The Arrowhead Company has proposed a dam at the Fork site 150 feet high which would give a capacity of 102,000 acre-feet for storing both East and West Fork flood waters. Borings made by the company at the dam site show bedrock to be at a maximum depth of 18 feet below stream bed. The natural rim of the basin at one point is only 110 feet above the stream channel at the dam site and the plans include the necessary raising of this bank 50 feet to give the desired capacity. The bank is here merely a narrow remnant of detrital deposit between the channel of the West Fork and the channel of the main river at a lower elevation than the West Fork. The peculiar topography of this locality can be best understood by reference to the map. The only foundation for a dam to raise the bank, as shown by excavations made by the company, is a layer of hardpan at a depth of 75 feet below the crest of the rim.

"Moderate leakage, provided the water reappeared as surface flow in the river, might not be a sufficient reason for condemning the site, for the water lost would help satisfy the owners of riparian lands and the appropriators on the stream below, but excessive leakage would impair the value of the reservoir."

Conkling and Gleason state in Bulletin No. 47:

"The Mojave plain slopes northward away from the dam site and the rim is only 100 feet above the stream channel at a saddle northeast of the dam site, necessitating an auxiliary embankment if water surface in the reservoir should be raised above that elevation.

"From the saddle the terrain drops 120 feet in about 600 feet to Mojave River bottoms. The question of percolation through this

alluvial ridge was considered by a board of engineers[1] which concluded as follows:

> 'The results of field examinations, laboratory tests, and theoretical computations of the probable ground-water flow through the saddle on the northern rim of the West Fork reservoir site, lead to the conclusion that it is a satisfactory foundation upon which to construct an earthen fill dam to impound water to an elevation of 3140 feet as proposed by your engineers.
>
> 'There will be a large rate of absorption through the sides and bed of the reservoir during the early period of its use, which probably will diminish from year to year, as the reservoir becomes silted up and as the ground water levels assume flatter gradients. Fortunately, the years of greater loss by absorption will be those of relatively smaller demand. We do not believe that the permanent loss by absorption will be sufficient to materially impair the value of the reservoir site.'"

This is the site proposed to be utilized in the projected transmountain diversion to Santa Ana Basin.

In a conversation with the authors, J. B. Lippincott, Consulting Engineer, who had reported on the feasibility of this site for Mojave River Irrigation District in 1923, expressed the opinion that the site should have further careful exploratory examination before construction of a dam were undertaken.

West Fork reservoir site No. 2. - This was surveyed by the Mojave River Commission[2] and a geological report was made but no exploration of the dam site was done. The dam site is in good granite. The cross section shows a width of about 600 feet at stream bed and 990 feet at 130 feet above stream bed.

West Fork reservoir site No. 3. - This was also surveyed by the Commission. No exploration work was done at the dam site, but it is in good granite. The cross section of the site shows a width of about 750 feet at the bottom and 1,075 feet at 130 feet above bottom.

Deep Creek reservoir site. - Dam proposed by Arrowhead Corporation was to be 150 feet high above stream bed, giving 2,000 acre-feet of storage. It was proposed as part of the diversion system from creeks east of Arrowhead Lake to the lake.

1/ "Permeability of the Northern Bank of the West Fork Reservoir Site," by J. A. Quinton, Charles Bradshaw and J. B. Lippincott. Unpublished report, 1923.

2/ State Bulletin No. 5.

Grass Valley reservoir site. - Dam proposed by Arrowhead Corporation was to be 90 feet high above stream bed, giving 7,600 acre-feet of storage. It was proposed as a regulator of Grass Valley Creek west of Lake Arrowhead to which it would be diverted.

Holcomb Creek reservoir site. - Dam proposed by Arrowhead Corporation was to be 70 feet high above stream bed, giving 1,000 acre-feet of storage. It was proposed to divert Holcomb Creek to Lake Arrowhead.

The surveyed capacity of known reservoir sites and estimated average annual discharges are shown in Table 46. Further studies are necessary to determine whether the water available would justify the capacities to which surveys have been made at the various reservoir sites or whether larger capacities are justified if found feasible.

TABLE 46. - Surveyed capacity reservoir sites and estimated average annual discharges 1/

Site	Elevation water surface above stream bed	Surveyed capacity	Average annual river discharge at site	
			1895-96 to 1904-05	1905-06 to 1933-34
	Feet	Acre-feet	Acre-feet	Acre-feet
Victor	140	350,000	42,000	90,300
Forks	160	113,500	25,000 2/	57,000 2/
			17,000 3/	33,300 3/
West Fork No. 2	130	34,800	12,400	24,300
West Fork No. 3	125	30,000	11,800	23,200
Grass Valley	80	7,600	1,160	2,600
Deep Creek	140	2,000	7,200	15,700
Holcomb Creek	60	1,000	3,700	8,000
Arrowhead 4/	160	60,100 5/	3,840	8,400
"	--	54,000 6/		

1/ State Bulletins No. 5 and No. 47.
2/ East Fork
3/ West Fork
4/ 80 percent completed.
5/ Projected
6/ Present

Underground Reservoirs

Along the Mojave from the Forks to Afton there is, as previously indicated, a series of underground reservoirs. The stream channel and bottom lands are of sand and gravel and receptive of water. Where the water table is not at the surface the stream percolates into its bed to appear as rising water lower down, regulated by these underground basins. Cyclic storage offered by these areas is a great asset to the development of Mojave Valley. Surplus waters during wet years is carried over as underground storage for use in dry periods. Thus far this cyclic storage has not been fully utilized.

Estimates of capacity of the underground basins made by Conkling are shown in Table 47.

TABLE 47. - Estimated Capacity of Underground Basins, Mojave Valley

District	Feet below ground surface			
	50	100	150	200
	Acre-feet	Acre-feet	Acre-feet	Acre-feet
Forks to Victorville	90,000	220,000	410,000	670,000
Victorville to Hodge	160,000	320,000	480,000	640,000
Hodge to Barstow, including Hinkley Valley	290,000	590,000	900,000	1,200,000
Total above Barstow	540,000	1,130,000	1,790,000	2,510,000
Barstow to Daggett	50,000	110,000	160,000	220,000
Daggett to Fault	150,000	360,000	560,000	770,000
Total below Barstow	200,000	470,000	720,000	990,000

Note: Voids on which this is based are 18 percent in river wash and 8 percent in old alluvium above Victorville, 15 percent Victorville to Forks of-the-Road Fault below Barstow and 11 percent below the Fault.

In discussing the utilization of the river Conkling points out that:

"There is no existing problem in Mohave River Basin of failing underground water supplies. On the contrary, after a period of many years of subnormal runoff the water table has fallen only slightly and native vegetation due to high water table is growing luxuriantly on many thousands of acres. Probably more than twice as much water is being consumed thereby as by all the beneficial uses in the valley. There were 6,000 acres irrigated in 1929 by water supplied from the river. Many thousand additional acres above Victorville, between Victorville and Barstow, and in Hinkley Valley are underlain by water supplied from the river. The water table is close to the surface under these areas and good wells are readily drilled.

"The obvious method of development would be by individual wells in these areas. It is a method which has been duplicated in many valleys in California. The results of such development would be:

"1. A drop in the water table.

"2. A decrease in the area of native vegetation, because the water table would not be high enough to support it, thus setting water free for beneficial use.

"3. Greater opportunity for floods to percolate into the streambed because of lowered water table and thus a decrease in the waste of floods past Afton. With the physical conditions along the Mojave and the very porous material in the streambeds, if the water table were lowered sufficiently from the Forks to Barstow and spreading done, the result might be practically complete salvage of flood waste.

"4. If sufficient area either overlying the river underflow or outside of this area were irrigated by pumping, overdraft might result with ultimate necessary decrease to the draft which could be sustained.

"An apparently obvious method by which the present use of water by native vegetation in the river bottom could be changed to beneficial use, would be to cut the cottonwoods, etc., in the bottom lands and substitute cultivated crops, just as already has been done in part. If the estimates of present consumptive use are near the actual facts and the native vegetation is using as much or more water per acre than is used by cultivated crops, this would not upset the regimen of the stream."

The results of a diversion to the Santa Ana Basin or development of additional acreage in the Mojave Valley would, if extensive, bring about a considerable change in the regimen of the river. In connection with an additional development, it is pointed out in Bulletin No. 47:

"..... If a greater draft were made on the Victor Basin the water table in dry years would be lowered, it would intercept the streambed farther downstream, rising water would decrease, the irrigated area now watered by gravity canals would be forced to pump to secure a supply in part at least, the surface stream which now quickly fills the sands below Lower Narrows and Bryman would be reduced, the water table below Hodge would be lowered, rising water farther downstream would decrease and water table would be lowered farther in reaches between rising water all along the stream to Afton. The same effect on all downstream points would be felt if additional draft were made anywhere along the river. The lowering would not be permanent unless the draft increased to a point where it was greater than the recharge, but the water table would be lower in cycles of low runoff than it now is and would be raised only by the percolation from the years of heavy flood to approximately the same level as would have been reached if no additional draft had occurred.

"The same condition would result if large pumping operations in the various basins were instituted to secure water for exportation to areas outside Mojave River influence. In this case the legal situation might offer difficulties."

Proposed Projects in Mojave Basin

Appleton Land, Water and Power Company. - Pending before the California State Emergency Relief Administration is a proposal involving some 22,000 acres of this company's holdings (see Frontispiece) centering at Hesperia. This plan was presented as offering opportunity for "removing unemployed people from the congested industrial centers; in removing unemployed from the charity rolls, and placing them on self-sustaining small farms." The development plans were outlined as follows, claim being asserted that their consummation would care for 4,000 heads of families and a total of 12,000 persons:

(a) Survey the entire property and stake out into 5-acre units, following the plans and regulations of the County Planning Commission.

(b) Clear and level the property for gravity irrigation.

(c) Extend the present water system for irrigating by means of open ditches and extend the present water system by means of pipes for a pressure water system for domestic uses.

(d) Grade and ditch the new roads on the property and plant trees along the right-of-way for purpose of windbreaks and for shade.

(e) Lay out a new townsite, park system and a recreational center.

On each 5-acre unit -

(f) Construct a modern well built 4-room house of a typical Spanish type, complete with electricity and pressure water installed.

(g) Set out along the exterior borders of each 5 acres, 150 assorted fruit trees and berry bushes, setting inside the line far enough to not interfere with the adjoining parcel.

(h) Gravity water to the high side of each 5-acre unit for irrigating.

(i) Chicken houses of the latest approved State Design to amply take care of 900 chickens. Should the purchaser desire to raise turkeys or geese instead of chickens, or to go in for dairying products, or to specialize on fruit or truck gardening, a proportionate charge will be made for the difference in cost.

(j) Set out an alfalfa patch for poultry green food supply.

(k) Set out a garden plot.

(l) Each acre represents a proportionate ownership in the water system and when the entire tract is fully developed the individual unit owners will own the entire water system.

(m) Give to each unit owner a membership in the Community Center with all the advantages thereof.

Included in the plan was the present Hesperia water system, consisting of "4 miles of 30 inch steel pipe, 2 miles of 14 inch steel pipe, 2 miles of concrete lined open ditch, and the head works on Deep Creek consisting of a 20 foot concrete dam. The system ends in a 58 acre foot earthen reservoir at the town site." According to the prospectus, "the present dam can be increased in height to provide additional storage and a dam can also be constructed on the West Fork which will practically double the capacity of the present system." The duty of water for alfalfa is assumed to be 1.50 acre-feet per acre on the East Mesa and 1.25 acre-feet per acre on this particular property, these estimates being based on a mistaken understanding of those appearing in State Bulletin No. 5. The riparian rights of the area are claimed to give it "a minimum of 30,000 acre-feet a year." The financial arrangement proposed is not set out in the correspondence to which the authors have had access, but are understood to have involved an initial payment of $1,000,000 by the Government, with which a mortgage of $700,000 on part of the acreage was to be paid off. The total investment was estimated to run several times the initial payment, instalments being provided for as the construction progressed.

This project involves land of generally good quality and its riparian position is an advantageous one, although just how it would fare before the courts in view of the extremely limited utilization its now asserted rights have had might not be as assumed in the prospectus. The plan is distinctly faulty in its assumption of an excessively economical duty of water. There was doubt whether the agency to which the proposal was addressed had the authority to proceed with such a project, and at the time this report was under preparation approval of it was still withheld.

The authors consider that the withdrawal of 30,000 acre-feet from the river for this project might have a proportionately equivalent effect on present and prospective future development of lands downstream that a diversion to Santa Ana Basin might have, with the possibly important distinction that a return flow might be expected from it, although not of appreciable amount if an alfalfa duty of water of 1.25 acre-feet per acre were actually attained. The authors consider this plan of doubtful practicability, although alfalfa production apparently would not be the basis of the project's industry.

Helendale ("El Mojave") project. - Also before the California State Emergency Relief Administration are revised plans for an extensive project near Helendale. This project was originally promoted six or seven years ago, but plans for it were dropped following the 1929 panic.

The present prospectus states that the primary purpose of the project is "to colonize land in the Mojave River Valley ..... with SERA farmers, placing a family upon each 20-acre tract of fully developed and planted land; with a well-designed modern farm house, a garden and family orchard, and with a 'down to the minute' cooperative harvesting, feeding, processing and marketing organization."

The original plans contemplated a 65,000 acre development on both sides of the river near Helendale, but this proposal was rejected by the SERA authorities on the grounds that (1) the project was too large and

the cost of development too great, the plan being stated to "propose the development of more irrigated land than there are duly qualified relief clients to handle, at least in San Bernardino County;" (2) the plan did not promise success based upon past experience in such endeavors; (3) the source and adequacy of the water supply were apparently questionable. The indications were asserted to be that "the cost of water development would be comparatively high. In all calculations, recognition should be given to the fact that many years will elapse before all this land would be put under cultivation, and in the meantime, the cultivated land would have to carry the overhead and interest charges on the uncultivated land; (4) the soil was described as being "of only fair quality, some of it apparently tending to alkalinity;" (5) the elevation was declared to "limit the number of crops that can be grown, and the comparatively short growing season lowers the average expected yield per acre as compared with a farm in the valley section." The suggestion was made, however, that plans be drawn for a much smaller project, and a revision was accordingly submitted later by which it was "proposed to develop the first step of the water production and conveyance plant with which to water this initial 2,000 acres; level and grade the land for irrigation; supply it with an underground concrete field piping system; plant it to alfalfa and silage crops; build a house, barn and corral on each 20-acre unit and provide a garden plot and family orchard of small fruits and trees. It (was) then proposed through community effort, to erect the first units of a central dairy cow feeding plant, the first unit of a central milking plant, and a milk processing plant, to house, feed and care for 2,000 dairy cows, milk them, process the milk and ship the product to the distributing plant in Los Angeles by insulated, refrigerated tank trucks. These plants (could) be expanded to an ultimate capacity of 5,000 cows each, as more land is brought into cultivation and more colonists are brought in. Additional major units of like size (could) be brought in from time to time until the entire available acreage of 65,000 acres, in the Mojave River Valley, is colonized and in full development."

The water supply was to be obtained from wells penetrating the gravels underlying a tract of water-bearing land. The total estimated cost of the original 65,000 acre project, including lands and water development, conveyance, conservation and development, was $85 an acre. Water supply estimates were supported in part by the following assertions by P. E. Fuller, Consulting Engineer:

> "The above reports and my own investigation disclose a known average annual flow of about 90,000 feet of water, which is supplemented by a very large but unknown quantity coming into the river basin above Helendale from the west, entering the Mojave River Valley above this project and the major portion of this water is absorbed into the vast underground alluvial formation beneath the flood plane of the Helendale Basin. The quantity of water fed into the basin from the extensive drainage area to the west is probably equal to the drainage from the main watershed to the south. (The above does not take into account the large percentage of return flow which will find its way back into the river channel after having been applied in the irrigation of contiguous lands.)"

The authors have already discussed (page 29) the possibilities of expanding the dairy industry of Mojave Valley. The revised plan for the El Mojave project reducing the initial unit to 2,000 acres represents a much more cautious venture than the original larger scheme, although even it is based upon various assumptions (as, for instance, that Los Angeles would provide a ready and profitable market for the milk) which might not prove to be well-founded. However, as far as the water-supply is concerned, so small an acreage should not prove a severe drain, whether or not the project's engineers were justified in their estimates of the entire "average annual yield" of the river as quoted above. When this paragraph was written, the revised plans were still awaiting action by the SERA authorities.

Other proposals. - While the authors were in Mojave Valley they were informed of proposals, then in merely preliminary stages, but which, if carried out, would involve areas in the lower part of the valley. One of these contemplated the irrigation of 3,000 to 5,000 acres adjacent to Yermo from the wells sunk by the Yermo Mutual Water Company or its predecessor. Table 10 shows that only 28 acres were irrigated in 1934 in Yermo township, but the wells are represented as capable of supplying water for a relatively large area. The authors see no likelihood of an early expansion at Yermo.

The other proposal involves a plan to irrigate some 60,000 acres near Newberry, by means of water to be obtained from wells. The cost estimate is $1,500,000 to be financed with money borrowed from the Federal Government. Employment of SERA labor is contemplated. Poultry and dairy ranches would comprise the project.

Although correspondence with the Government has been started, the proposal is as yet little more than a suggestion. Cost estimates so far advanced are too low, and the water supply available for so large an acreage is obviously more than of doubtful sufficiency. If undertaken at all, it is apparent that the tentative plans will have to stand drastic revision.

Proposed Diversion to Santa Ana Basin

Brief reference was made in the chapter on "History" to the Arrowhead Lake development. Since this forms the basis for the proposed plan which led to the original request for the study upon which this report is based, it is discussed below at somewhat greater length. Tait, in State Bulletin No. 5, recited the history of the Arrowhead projects up to the time his bulletin was written (1917) as follows:

> "The predecessor of the present Arrowhead Reservoir and Power Company[1/] was the Arrowhead Reservoir Company, organized in 1891, the principal stockholders being Cincinnati capitalists. The original plan was a colossal undertaking. It was proposed to construct a main reservoir in Little Bear Valley which would impound the natural drainage of Little Bear Creek, a tributary of

1/ Now (1935) Arrowhead Lake Corporation.

Deep Creek. An inlet tunnel, now partly constructed, was to be made from the reservoir eastward to Deep Creek and extended from this stream to Crab and Holcomb creeks to collect all drainage above the tunnel and carry it into the reservoir. Diversion dams and regulating reservoirs were to be located at Deep, Crab and Holcomb creeks and the flow of the smaller streams was to enter the tunnel through shafts. All of these works would be in the Deep Creek watershed. Another reservoir was to be constructed in Grass Valley, westward of the main reservoir and on a tributary of the West Fork of the Mojave River, and this supplemental basin was to be connected with the main basin by a tunnel. Two other reservoirs were to be located in mountain flats, the sites for which were later abandoned. Water was to be taken from the main reservoir by an outlet tunnel through the San Bernardino Range and delivered for the irrigation of lands south of the mountains. The company had no lands for sale and made no contracts for the delivery of water.

"A masonry dam, to form the main reservoir, was begun on Little Bear Creek, but by the time the foundation was constructed it was found that suitable rock in sufficient quantity to construct a masonry dam was not to be had near the site. This caused a suspension of construction which was prolonged for a number of years. Data on the amount of water for storage had been meagre and the supply had been overestimated. In 1892 a series of precipitation and runoff measurements was begun throughout the watershed which was continued for 13 years before construction was resumed.

"Until 1895 the development of power had not been considered in connection with the project. About that time, when it became known that long transmission of electrical power was practicable, it was planned to utilize the energy of the water in its descent on the southern slope of the mountains.

"In 1905 the property was transferred to a new corporation, the Arrowhead Reservoir and Power Company, capitalized at $6,500,000 with nonassessable stock of which $500,000 was 5 per cent preferred and the remainder common stock. Shares representing about $600,000 par value were issued and placed in the hands of a trustee, no payments having been made on these shares. Some of the stockholders have taken notes of the company for other obligations, but the company has no indebtedness outside of the stockholders.

"The type of dam for the Arrowhead site was changed to a semi-hydraulic fill with concrete core. The plan of outlet works was also modified. The Burcham Ranch, now called Rancho Las Flores, containing 5,240 acres and including the Forks reservoir site on the West Fork of Mojave River near the Forks, also two dam sites farther upstream on the West Fork and known as the West Fork sites numbers 2 and 3, were acquired. It was proposed to convey the water in Little Bear Valley reservoir to the Forks reservoir, using the intervening drop for power development. The water would be combined in the Forks reservoir with that received from the natural drainage of the West Fork. This lower reservoir was then to be

drained by a tunnel through the mountain range to the south side, where another power drop would be located and below which the water would, as under the former plan, be delivered for irrigation in San Bernardino Valley.

"About 1909 some of the owners of riparian lands on Mojave River, including the Hesperia Land and Water Company, filed suits to prevent the company diverting water from the watershed, but the cases have not been brought to trial. In 1912 application was made to the California Railroad Commission for permission to issue $4,000,000 in bonds when riparian land owners again opposed the plans of the company by protesting against the granting of the application. The application was denied, without prejudice, for the stated reason that the company's title to water was uncertain until the cases were decided by the courts. The record of the hearings conducted by the commission on the application shows the following:

Valuation put on property at time of reorganization	$1,191,000
Spent by new company since reorganization	923,204
Principal owed by new company	793,796
Interest owed by new company	126,589
Total	$3,034,589

"About this time the company, or a trustee of some of the stockholders, began to purchase riparian lands on Mojave River mainly for the purpose of quieting opposition from adverse water right claimants, and 1,000 acres just below the Forks and 3,200 acres, together with most of the older and more useful ditches between Victorville and Barstow, were acquired. This property included the Westwater lands below Victorville.

"It had been the intention to purchase more riparian lands, but owing to the decision of the State Supreme Court about this time to the effect that flood waters of a stream could not legally be diverted from the natural drainage basin,[1/] a radical change in plan was adopted which made this no longer necessary. It was now decided to use the water for the development of power and irrigation on the north side instead of the south side of the mountains. In 1914 an offer, which was not accepted, was made to the city of San Diego to sell the water from the system, the diversion from the watershed for domestic use not being illegal.

"In addition to agricultural lands below the Forks, the company holds about 12,000 acres in the mountains, mainly in the Little Bear Valley, Grass Valley and Forks reservoir basins. The company claims riparian rights appertaining to the extensive lands above and below the Forks, also appropriation rights on all streams above the Little Bear Valley reservoir inlet dating from 1890 and on the West Fork and Deep Creek dating from 1905."

1/ Miller & Lux vs. Madera Canal and Irrigation Company, 155 Cal. 60.

Thus, from its inception, the Arrowhead development had in contemplation the use of Mojave River water south of San Bernardino and San Gabriel mountains, and various plans, including the one now under consideration, have continued the interest in that possibility in one form or another. The early plans gave no thought to storage on the lower river, either below or immediately above the junction of West Fork and East Fork (Deep Creek), but subsequent opposition by lower water users and riparian claimants led to the consideration of storage at Forks reservoir site on West Fork immediately above its junction with East Fork and at two other sites on West Fork immediately above. These were involved in a plan given serious consideration by Pasadena in 1923, which had in view the incorporation of the storage in a water supply system for the city. San Bernardino and other communities have given the Mojave some consideration.

For a strictly municipal supply, the earlier plans of storage in what is now Arrowhead Lake, with its proposed and partly constructed feeder tunnels, might have served, but the later transformation of the reservoir into a recreational lake appeared to preclude this. The larger project of storage at Forks reservoir site, involving a tunnel about 10 miles long from the reservoir to the mouth of Devil Canyon on the south side of the mountains and a conduit line running westward along the foot of the San Gabriels was considered generally feasible, but was given up for various reasons, among them the prospective legal difficulties over water rights.

In 1923 the property was acquired by the present company in whose name it still stands. Efforts to continue the early plan have been abandoned by the Corporation. The reservoir forms a beautiful mountain lake. A resort of considerable fame has been established with the lake as a nucleus. Much of the land bordering or near the lake has been subdivided and sold.

The following construction has been completed (as described in State Bulletin 47):

Thirteen thousand feet of a concrete-lined tunnel 6' x 7' in section from Deep Creek to Arrowhead Lake. There remains 5370 feet unbored.

A 4' x 6' concrete-lined tunnel 5102 feet long from the gate tower at Lake Arrowhead to Willow Creek.

A similar tunnel as part of the outlet system, 2500 feet long. Bore completed but not lined.

A 5' x 7' concrete-lined tunnel 2800 feet long from Grass Valley to Arrowhead Lake.

Arrowhead Dam, a semi-hydraulic fill with concrete core, to a height of 200 feet above stream bed. As projected it was to be 27 feet higher. Present capacity of reservoir is 54,000 acre-feet. The projected capacity is 61,000 acre-feet. Outlet works are complete.

No work has been done on the remaining features of the project.

The present (1935) land holdings of Arrowhead Lake Corporation are shown on the Frontispiece map.

In 1929 some consideration was given to the possibility of diverting water from the Mojave River to Santa Ana Basin by the Division of Water Resources, as it states in California State Bulletin No. 31, "Santa Ana River Basin," that:

"....... The average annual run-off from the mountain headwaters was estimated at 98,000 acre-feet in Bulletin 5, 'Flow in California Streams,' Division of Engineering and Irrigation, State Department of Public Works.

"Preliminary estimates indicate it is feasible, from the physical standpoint, to control the run-off of the river so that an average annual amount approximating 70,000 acre-feet can be diverted through the mountains to Santa Ana Basin. Diversion of such an amount would require purchase and control of Arrowhead Lake and diversion of some of the tributaries of Deep Creek into it. Without control of Arrowhead Lake an average annual amount estimated at approximately 60,000 acre-feet can be brought to Santa Ana Basin.

"The approximate construction cost of diverting 60,000 acre-feet to Santa Ana Basin and distributing it along the upper margin of the basin from San Bernardino to Pomona is estimated at $9,000,000. The diversion of this amount would involve acquisition of water rights on Mohave River to an unknown extent and the complete cost would be greater than that sum.

"The practicability of the engineering features of this plan depends on the feasibility of Forks Reservoir, the foundations for which have not been explored. Forks Reservoir lies on West Fork just above its junction with Deep Creek. It has been surveyed to a capacity of 113,000 acre-feet with water surface 160 feet above stream bed. The cost per acre-foot of water diverted to Santa Ana Basin and distributed along the upper margin of the basin can not be estimated accurately because of lack of knowledge as to cost of purchasing rights. After paying for this, the cost might be as large as that for water obtained through the Metropolitan Water District.

"Estimates of cost of diverting other smaller amounts have not been made, but indications are that such amounts can be diverted from West Fork to Santa Ana Basin at reasonable cost for construction features. In this case also, nothing is known as to the cost of purchasing rights. Diversion of an average annual amount of from 15,000 to 20,000 acre-feet would leave sufficient water for present development in Mohave Basin, plus some expansion.

"The present irrigated area in Mohave Basin is approximately 8,000 acres. The sixth biennial report (1916-1918) of the Department of Engineering, California, gives the gross agricultural area

in Mohave Basin as 325,000 acres. Two irrigation districts on the east and west mesas above Victorville, covering a gross area of 100,000 acres, have been proposed. The biennial report states that the soil is of good quality. One of these irrigation districts is being promoted at present, but the other is quiescent.

"Diversion of any part of Mohave River to Santa Ana Basin will curtail irrigation possibilities in Mohave Basin. In addition to removing water from an area of deficient supply it would transfer it to an area which, although short of water now, has potentially a complete supply through plans for other importation.

"The utmost possible diversion from Mohave River, together with salvage of local waste in Santa Ana Basin is believed to be more than sufficient to offset the present shortage in Santa Ana Basin, but the margin is not large. Continued development in Santa Ana Basin would have to depend on still other outside supplies.

"The Mohave River, if entirely diverted to Santa Ana Basin, would relieve the present shortage in Chino Basin and around San Bernardino, but it is believed other supplies would eventually have to be imported into this area, even if Mohave River were brought in and used entirely for it."

In explanation of the proposal upon which this report was initiated (see Introduction), Francis Cuttle, as chairman of the committee representing the agencies which addressed the letter of April 17 to Secretary Wallace, gave the authors the following statement:

"The idea of bringing any water which may be available from the Mojave River above the amount that is being put to beneficial use has been discussed for a long time by parties in the counties of San Bernardino, Riverside, and Orange, California. This idea took more definite form during the year 1934. Conferences were held at Riverside during 1934-35 by representatives of organizations in the three counties charged with maintaining water supplies; and at all of these conferences it has been understood by the participants that if it should be found that there is surplus water available on the Mojave River, and that the expense of bringing same into the Santa Ana River watershed was not unreasonable, that any such water which might be found to be available would be divided equally between the three counties, it being also understood that in the event any one of these counties did not wish to avail itself of the opportunity to secure its proportion of the total amount which might be diverted, then and in that event such water should be divided equally between the other counties.

"In my opinion, the future of the Santa Ana Basin depends either upon the importation of water or the deportation of people."

PLATE 3.

PLAN PROPOSING THE TRANSMOUNTAIN DIVERSION OF THE SURPLUS WATER (IF ANY) OF MOJAVE RIVER AND DISTRIBUTING IT IN SANTA ANA BASIN
(By Finkle, Rowe, and Browning)

A report prepared in 1933 entitled "Report on Water Supply from Mojave River for the San Bernardino Valley and Orange County, California," by F. C. Finkle, W. P. Rowe, and C. R. Browning, Consulting Engineers, outlines a plan to divert 40,000 acre-feet from the Mojave River to Santa Ana Basin. Since no other detailed plan is available, it will be used for the purpose of the following discussion. At the request of the authors, Browning and Rowe briefed the plan as follows. The description can best be followed by reference to Plate 3:

"The plan of diversion of surplus water of the Mojave River, as proposed by Engineers Finkle, Rowe, and Browning, provides for the use of the West Fork reservoir site, having a storage capacity of 112,000 acre-feet. A diversion tunnel would carry the water from this reservoir through the San Bernardino Mountains to the Santa Ana River watershed in the vicinity of Devil Canyon north of the City of San Bernardino. At this point power development would be made by utilizing the difference in elevation of the diversion tunnel and the intake to the diversion system at the mouth of Devil Canyon, some 1200 feet lower.

"In connection with this reservoir, it is proposed to complete the Deep Creek diversion tunnel under the original plan of the Arrowhead Reservoir and Power Company for diverting water from the headwaters of Deep Creek into Lake Arrowhead. It is not intended that Holcomb Creek would be diverted. Lake Arrowhead would be used as a regulating reservoir only and the water level would never be lowered below the 5100 foot elevation, thus guaranteeing to the property owners their present lake elevation for all time in the future. The outlet system from Lake Arrowhead would be completed to the long ridge just north of the East Fork of the West Fork of the Mojave River and would be carried along this ridge to a penstock leading into the diversion tunnel from the West Fork reservoir. The head at this penstock pipe is 1800 feet, and a power development is proposed. Surplus water from Lake Arrowhead would be allowed to spill into Grass Valley Creek, by which it would reach the West Fork reservoir for storage at that place. The safe yield of the Upper Deep Creek and Lake Arrowhead system is estimated at 12,000 acre-feet per annum, and the West Fork system at 28,000 acre-feet, making a total of 40,000 acre-feet per year as the amount to be diverted to the Santa Ana watershed.

"At the mouth of Devil Canyon a diversion system is planned to carry the water in conduit to the canals serving the Riverside County interests. The water mains of the City of San Bernardino Water Department already extend to the mouth of Devil Canyon and water could be turned directly into this system without any further expenditure. To serve the interests in Orange County and the west end of San Bernardino County, a gravity conduit would extend westerly from the mouth of Devil Canyon to a point north of Fontana. At this point a canal to serve the west end of San Bernardino County would continue westerly, while the Orange County water would be carried southerly

and delivered into the Santa Ana River at the Riverside Narrows. There is a perennial stream from the Riverside Narrows to the intakes of the main canals in Orange County, and the Orange County water would be permitted to flow in this stream as it is believed there would be very little additional loss by evaporation and transpiration by the addition of this new water to the present stream."

An estimate of the available supply from Lake Arrowhead was prepared by Finkle, Rowe, and Browning on the basis of determining the safe yield from a storage reservoir, the theory being that no greater decrease in the safe yield is permissible than 25 percent. They state:

"By this method the forty (40) seasons from 1892-1893 to 1931-32, inclusive, will produce a seasonal draft from the reservoir (Lake Arrowhead) of 12,000 acre-feet with a single exception of the season 1899-1900 in which a 9,000 acre-feet draft would have been obtainable," and further, "that the safe draft from the West Fork Reservoir during the forty (40) seasons considered would not have fallen below 28,000 acre-feet except for six seasons from 1897-1898 to 1903-04 inclusive, during which six seasons a seventy-five per cent (75%) supply was available except during two seasons in the period, in which the supply fell somewhat below the seventy-five per cent. Our studies show that the 28,000 acre-feet per annum draft from the West Fork Reservoir is the best development, as the loss by reducing the draft below 28,000 acre-feet would be much greater than the slight loss during the six seasons out of forty in which the supply falls below 28,000 acre-feet. Thus the safe yield from the Mojave River drainage, which may be secured through storage in Lake Arrowhead and the West Fork reservoir, amounts to a mean of 40,000 acre-feet per season.

"It appears that the aggregate flow of the East Fork and West Fork of Mojave River, as a mean throughout the forty year period, amounts to 91,517 acre-feet per season. If the full 40,000 acre-feet per season be diverted by the project herein designed, the deficiency in dry years being made up by greater diversions in the wet years, there will still remain 51,517 acre-feet of mean average seasonal discharge from the Mojave River to supply all needs of the lower lands and basins along the stream. This quantity is far in excess of anything which can be utilized on land along the Mojave River, including both riparian and non-riparian lands in its valleys. At the present time there are less than 6,000 acres of land cultivated along the entire length of the Mojave River below the forks, and the actual requirements for the irrigation of these lands would not average in excess of two acre-feet per annum or approximately 12,000 acre-feet."

After analyzing the records shown in the report above referred to, the authors concluded that some of the estimates for mean annual run-off were too high. This was particularly true for the year 1923-24, the figure for which the authors revised[1] (see Table 29). Using the revised

---

[1] With Mr. Rowe's concurrence.

figures, Table 48 was prepared to show what the effect of the proposed diversion to Santa Ana Basin of 40,000 acre-feet would have been on the discharge of the Mojave River below the Forks, if Lake Arrowhead and Forks (West Fork) reservoirs had been in operation for such purpose from 1892-93 to 1931-32. The estimated mean discharge of 89,500 acre-feet is approximately the same as Conkling's estimate, but is lower than the one shown in the Finkle-Rowe-Browning report.

Table 49 has been prepared with the purpose of illustrating the probable effect on the water supply in the Upper, Middle, and Lower valleys, if the proposed diversion had been an actuality during the 40-year period 1892 to 1932.

The consumptive use of water for agriculture shown in Table 49 is based on present irrigated area. It seems likely to the authors from the computations summarized in the table that, considering an equalizing series of years, a diversion of 40,000 acre-feet annually would not curtail the present irrigation use between the Forks and Victorville, that it would produce some deficiency between Victorville and Barstow, and that it would almost certainly produce a substantial deficiency below Barstow. These inferences are based on the important assumptions that (1) run-off of future years would approximate the run-off of the periods represented by the record; (2) that all water applied above the three acre-feet per acre allowance for consumptive use would be recovered for reuse; and (3) that no curtailment of use by native vegetation would be brought about.

All three assumptions are subject to challenge. No guarantee as regards the first assumption is, of course, possible. As regards the second, there is no proof to be offered; indeed, it is more than likely that some loss above the consumptive use would take place, at least so far as availability is involved. An assumption that all water above the aggregate of consumptive uses is available for diversion elsewhere is subject to valid criticism. For example, with three major basins of use it matters relatively little how much water is pumped and applied in the upper basin, for any water in excess of the consumptive use rejoins the ground water and becomes available for reuse, either in the same or in a lower basin. The same thing may be said of use in the second basin. In the last basin downstream, however, the return water is not so readily recaptured, and quantities applied but not used consumptively may pass beyond a point of recovery and be no longer available for reuse; its requirement is therefore represented not merely by consumptive use, but by the larger amount involved in actual irrigation.

As regards the third assumption, it is believed that a curtailment of use by native vegetation is possible and that it will have to be made if a substantial increase in agricultural use takes place either in the valley itself or by diversion elsewhere.

In this connection, reference is again made to Table 10, where a total of 2,922 acres in "woodland pasture" and a total of 352 acres of "woodland not used for pasture" are shown. Since these acreages are in

TABLE 48. - Effect of proposed transmountain diversion on discharge of Mojave River below Forks[1]

Period	Years	Deep Creek (East Fork)			West Fork	Mojave River below Forks		
		Discharge	Diversion	Amount passing Forks	Spill from proposed Forks Reservoir	Discharge after diversion	Normal discharge	Loss due to diversions
		Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet	Acre-feet
1892-93 to 1904-05	13	40,000	17,100	22,900	500	23,400	64,700	41,300
1905-06 to 1921-22	17	74,800	22,900	51,900	24,600	76,400	122,600	46,200
1922-23 to 1931-32	10	44,800	19,600	22,200	5,700	27,900	65,400	37,500
1892-93 to 1931-32	40	55,200	20,200	35,000	12,000	47,000	89,500	42,500

1/ Based on proposed diversion of 40,000 acre-feet per year by means of storage in Lake Arrowhead and Forks reservoirs as outlined in "Report on Water Supply from Mojave River for San Bernardino Valley and Orange County, California," by F. C. Finkle, W. P. Rowe, and C. R. Browning, Consulting Engineers.

TABLE 49. - Estimated average annual river discharge (if proposed transmountain diversion of 40,000 acre-feet had been in effect) and consumptive use of water, Upper, Middle, and Lower valleys, for specified periods

Item	Period			
	1892-93 to 1904-05	1905-06 to 1921-22	1922-23 to 1931-32	1892-93 to 1931-32
	Acre-feet	Acre-feet	Acre-feet	Acre-feet
Discharge Mojave River below Forks after diversion 40,000 acre-feet	23,400	76,400	27,900	47,000
Forks to Upper Narrows				
Consumptive use:				
Agriculture and domestic 4,000 acre-feet) Native vegetation 7,000 acre-feet)	11,000	11,000	11,000	11,000
Apparent surplus 1/	12,400	65,400	16,900	36,000
Upper Narrows to Barstow				
Consumptive use:				
Agriculture 11,000 acre-feet) Domestic and industrial 400 acre-feet) Native vegetation 18,000 acre-feet)	29,400	29,400	29,400	29,400
Inflow 2/	7,000	7,000	7,000	7,000
Apparent surplus (or deficiency) 3/	-10,000	43,000	-5,500	13,600
Barstow to Afton				
Consumptive use:				
Agriculture 3,300 acre-feet) Domestic and industrial 700 acre-feet) Native vegetation 14,000 acre-feet)	18,000	18,000	18,000	18,000
Apparent surplus (or deficiency) 3/	-28,000	25,000	-23,500	-4,400

1/ Discharge measurements by U. S. Geological Survey at Forks and Upper Narrows from October, 1930 to April, 1935 show a net loss of 5,100 acre-feet, which indicates that there is probably an inflow between these two points. If such is the case the apparent surplus shown is too low.
2/ See Bulletin No. 47, pages 58 and 63.
3/ Minus sign (-) indicates deficiency.

farms now operated, it is to be presumed that their trees have usefulness justifying their preservation. The remainder of the 7,800 acres of wet lands "supporting principally cottonwoods but also some tules and salt grass" may be presumed to be made up mostly of areas outside present farms and using water "non-beneficially," as described in Bulletin No. 47. Some such groves might perhaps be made into parks, but otherwise they could be sacrificed to permit a more economical use of the water they now consume. Such sacrifice would logically be expected to be brought about by the agencies needing the water.

As heretofore indicated, Table 49 takes no account of the possible increase of the agricultural area in farms now operated. It likewise takes account only by the footnote of the apparent inflow between the Forks and the Upper Narrows. If a doubling of the agricultural area should take place in this section, the estimated consumptive use by crops would be substantially increased -- not necessarily doubled, as the areas of grain and other crops which are economical in their use of water, might increase proportionately more than the alfalfa area. In that event, the apparent inflow might be sufficient to care for the increased acreage. However, the record of the past five years indicates that this inflow is of uncertain and fluctuating amount, and the authors are not inclined to stress its potentialities until a longer record of measurements is available. On the other hand, preliminary studies by the Bureau of Agricultural Engineering indicate there is an excellent opportunity to replenish the underground water supply in this basin in event of overdraft, by means of spreading flood waters.

To take proper account of the possible increase in agricultural area between the Upper Narrows and Barstow, the allowance for consumptive use should be increased by, say, 10,000 acre-feet. Notwithstanding the claim of proponents of El Mojave project, the authors find no convincing evidence of a substantial inflow to that section of the river except the 7,000 acre-feet per year estimated by Conkling. Therefore, an approximate doubling of the consumptive use allowance for crops for the area below Barstow should also be made, in a consideration of the future building up of the present farms.

It is true, of course, that any substantial increase in the cropped acreage might involve parts of the areas now in native vegetation, and it is in point here to say that if the water table can be lowered without reaching an uneconomic pumping level, the deficiency of supply might be made up from the water stored underground and the resultant decrease in use by native vegetation, some of which would die.

Any extensive development of the water resources of the Mojave Basin must contemplate utilization of underground reservoirs. Such development would disturb the present regimen of the stream considerably. When considering the regimen of the river above Barstow it should be realized that the cyclic storage offered by the various basins has been utilized to very little extent except in Hinkley Valley. As indicated by Table 47, the upper 50 feet of these underground reservoirs have the following capacities: Forks to Victorville, 90,000 acre-feet; Victorville to Hodge, 160,000 acre-feet; Hodge to Barstow (including

Hinkley Valley), 290,000 acre-feet; and below Barstow, 200,000 acre-feet. Usually the greatest fluctuation in any underground water basin, such as those in Mojave Valley, will take place at the upper end where the water enters, and the least variation will occur where the water leaves at the lower part. If a deficiency occurring during a dry period (for example, in the Hinkley Valley) is to be offset during a wet period of the cycle, more use must be made of cyclic storage. This would entail higher pumping lifts in some areas, but not to the extent of a uniformly increased lift over the entire area. This is the same condition that irrigators from wells have had to face for decades in other underground basins of southern California. In other words the water level is pumped lower in the dry periods and the floods of the wet periods restore the basin to its former level, provided there is no overdraft. However, in areas where irrigation depends entirely on pumping, such as Hinkley Valley, they are usually prepared for temporary shortages. For example, if the shortage in the Hodge-Hinkley-Barstow basin should average 10,000 acre-feet per year for 10 years, it would account for 100,000 acre-feet out of a total of 290,000 acre-feet (storage capacity) in a 50 foot lowering in this basin, or about 17 feet for the entire area. Since, as stated before, the most violent fluctuations would occur near the upper end of the basin, it is doubtful whether the average decline in the lower end where most of the present irrigation is practiced would exceed 13 feet. A greater lowering along the river will result in better efficiency of absorption of stream flow and less use of water by native vegetation.

Hence, the authors infer from Table 49 that even with the salvage of a substantial part of the water now consumed by native vegetation, and on the basis of assumptions (1) and (2), (page 108), if 40,000 acre-feet were first taken away, the "apparent surplus" shown in the table would not meet present agricultural, domestic, and industrial needs of the entire valley; or, putting the matter a little differently, that unless a substantial portion of the "non-beneficial" were corrected, no more than 15,000 to 20,000 acre-feet could safely be diverted across the mountains.

Table 49 appears to show further that if the agricultural use were confined entirely to the area above Barstow and the periods represented in the table were duplicated, 25,000 to 30,000 acre-feet could be taken out without curtailment of consumptive use by crops and native vegetation, although undoubtedly the latter would suffer during years of exceptionally low supply. This is on the assumption that the low annual discharges would be offset by those higher than the average at brief enough intervals to prevent a damaging increase in pumping lifts.

Notwithstanding the apparent purport of Table 49, as analyzed above, the authors feel that any diversion of Mojave River water outside its watershed should be made only after care is taken of the normal agricultural and industrial needs of the valley itself. The discussion in previous chapters of this report has been intended to indicate what those normal uses are or may become. If climatic history is repeated, there will be years -- even series of years -- when the removal of 40,000 acre-feet would leave almost no water at all for use in the valley, except what may have been stored underground in previous years.

For example during the 10-year dry period 1895-6 to 1904-5, the mean annual discharge below the Forks after a diversion of 40,000 acre-feet, would have been 13,600 acre-feet, which is very little more than the present estimated total consumptive use (11,000 acre-feet) in the section between the Forks and Victorville. In fact, in six of the years of this period, the annual discharge would have been less than 5,500 acre-feet, while for three consecutive years (1897-8 to 1899-1900) the surplus below the Forks would have totaled only 3,800 acre-feet.

Hence, the valley's rights should stand in the preferred position, and outside claimants should be satisfied with what is left, whether it be 40,000 acre-feet or some other amount. In other words, provision should be made to release stored water to the valley if it is needed there to support whatever may be adjudged beneficial use, and to the extent of removing such a deficiency as might exist without it, before diversion to the other side of the mountains is begun in any year.

The preceding discussion has assumed that the proposed diversion can legally be made. The legal aspects are discussed under the heading "Probable Legal Status of Water Rights."

Probable Legal Status of Water Rights[1/]

The California Supreme Court handed down on January 31, 1935, what was undoubtedly its most important water-right decision in many years, the case being that of Peabody et al. vs. City of Vallejo, 89 Cal., Dec. 165, 40 Pac. (2d) 486, Jan. 31, 1935. The opinion of the court was unanimous. Peabody and others were the owners of lands riparian to Suisun Creek; they sought to enjoin the City of Vallejo as an appropriator from storing any of the waters of Gordon Valley Creek, a tributary of Suisun Creek, claiming that they were entitled to the full flow of the creek regardless of the reasonableness of their use of the water.

The court held that since the adoption of Section 3 of Article XIV of the State Constitution in 1928, the old doctrine of riparian rights has been modified. It concluded that the rule of reasonable use enjoined by that section "applies to all water rights enjoyed or asserted in this state, whether the same be grounded on the riparian right or the right, analogous to the riparian right, of the overlying landowner, or the percolating water right, or the appropriative right."

The decision was laid on broad grounds. Much was said about the public welfare, about "substantial" benefits and damages, and about the reasonableness of the use of water. The constitutional amendment limiting riparian rights to reasonable and beneficial uses was accepted as a mandate that was plain, positive, and admitted of no exception, and that reflected the present policy of the State with reference to the use of water. The court undertook to state principles under which the conservation of unused waters for beneficial purposes could be brought about -- principles which would recognize the proper rights of the riparian owners, "but still place the law of the state in such condition that he may not, by assuming an arbitrary position, forestall

1/ This discussion was prepared with the assistance of Wells A. Hutchins, Irrigation Economist, Bureau of Agricultural Engineering.

by injunction proper programs of conservation, or assert such claims for compensation for any alleged infringement of his right as are fanciful and would be prohibitive." In other words, the "hold-up" value which the riparian right has apparently enjoyed since the Herminghaus decision is greatly reduced.

A second important decision was that in the case of Lindsay-Strathmore Irrigation District vs. Consolidated Peoples Ditch Company and Tulare Irrigation District vs. Lindsay-Strathmore Irrigation District, 89 Cal. Dec. 750, May 3, 1935.

A telephone call to the Clerk of the Supreme Court on June 12 disclosed that no petition concerning an appeal to the United States Supreme Court had been filed with the California Supreme Court to date, in either case. The time for filing had expired in the Peabody case; the Clerk stated that application for writ of certiorari (to review the case) may have been made at Washington, but considered it very doubtful. The time for filing had not expired in the Lindsay-Strathmore case.

As to the possible attitude of the United States Supreme Court on limitation of riparian rights: A decision by that Court in the case of California-Oregon Power Company vs. Beaver Portland Cement Company, April 29, 1935, held that following the Desert Land Act of 1877, if not before, all non-navigable waters then a part of the public domain became subject to the plenary control of the States, with the right in each to determine for itself to what extent the rule of appropriation or the riparian doctrine should obtain. Stanley F. Davie, Attorney for the Federal Land Bank of Berkeley, in a review of this case stated that the United States Supreme Court "has made an interpretation which will unquestionably clear the way for state statutes intended to abrogate or limit riparian rights;" and one of his conclusions is that "It leaves the states free to exercise their police power to abrogate or limit water rights which attach to lands patented subsequent to 1877."

In considering various pending plans for large-scale agricultural development in Mojave Valley, as well as the proposal that Mojave River water be diverted to Santa Ana Basin, the authors gave thought to the possible effect which the decisions above cited might have. Three principal questions appeared to need answers. These are discussed below:

Question 1. What legal obstacles now stand in the way of the diversion from one watershed to another?

The authors are not aware of any legal obstacles in the way of a diversion, by appropriation, from one watershed to another in California. A riparian owner, however, is limited to the watershed, if he relies on his riparian right; for riparian lands do not extend beyond the margin of the watershed.

Change of place of use may not be made if it affects other vested rights adversely. That is, if vested-right users depend upon return flow from irrigated lands, to change the location of use of water (which yields the return flow) out of the watershed would injure these vested-

right users. This is, of course, different from establishing the place of use of a new appropriation.

Waters are actually taken from one watershed to another in various States, including California. In E. Clemens Horst v. New Blue Point Mining Company, 177 Cal. 631, waters from Yuba River were being taken to Grass Valley, abandoned by appropriators and discharged into Wolf Creek tributary to Bear River, where they were again being appropriated and taken out of the watershed of Bear River. The question was whether riparian owners on Bear River could enjoin the diversion out of Bear River watershed; held that they could not, as the waters were foreign. The court said that the first appropriator "may not be deprived of the right to the use of it, even outside of the watershed of Wolf Creek."

The recent Lindsay-Strathmore case, in fact, involved the transportation of water out of the Kaweah watershed. The bare right to take water out of a watershed was not in controversy; the question was whether there was a surplus, above the needs of riparian owners and prior appropriators, which would be available to Lindsay-Strathmore Irrigation District. The Supreme Court announced a number of rules which should guide the trial court, and sent the case back for re-trial as to the specific quantities the various parties were entitled to, before it could be determined whether or not there was a surplus available for the District.

The authors believe that taking water out of the Mojave watershed would not be enjoined unless it deprived someone in the watershed of water to which he was entitled.

Mr. Spencer Burroughs, attorney for the State Division of Water Rights, in a telephone conversation (June 14) said that the Division accepts applications to appropriate water for use outside a watershed; that there is nothing illegal about it; that it is done in many cases.

Question 2. How do the recent decisions affect rights of riparian owners who have not exercised them?

The Lindsay-Strathmore case, which is later than the Peabody, announced the following rule (among others) to guide the trial court:

At p. 770, speaking of the new doctrine set forth in "Peabody v. City of Vallejo," the court says: "The trial court, under the new doctrine, must fix the quantity required by each riparian for his actual reasonable beneficial uses, the same as it would do in case of an appropriator. The new doctrine not only protects the actual reasonable beneficial uses of the riparian, but also the prospective reasonable beneficial uses of the riparian. As to such future or prospective reasonable beneficial uses, it is quite obvious that the quantity of water so required for such uses cannot be fixed in amount until the need for such use arises. Therefore, as to such uses, the trial court, in its findings and judgment, should declare such prospective uses paramount to any right of the appropriator. By such declaratory judgment, the rights of the riparian will be fully protected against the appropriative use ripening into a right by prescription, but, until the riparian needs the water,

the appropriator may use it, thus, at all times, putting all of the available water to beneficial uses. The trial court might well, by appropriate provisions in its judgment, retain jurisdiction over the cause, so that when a riparian claims the need for water, the right to which was awarded him under such a declaratory decree, the trial court may determine whether the proposed new use, under all the circumstances, is a reasonable beneficial use and, if so, the quantity required for such use."

Question 3. What recourse would non-riparian pumpers have from the anticipated (or proved) effects of a diversion which would increase their pumping lifts?

A user of ground water underlying his land has a correlative right with other overlying landowners to make a reasonable use of the common underground supply. The Lindsay-Strathmore case has the following regarding restrictions upon his right:

> "It is to be noted that the new doctrine embodied in the constitutional amendment, as interpreted in the Peabody case, not only applies the doctrine of reasonable use as between riparian and appropriator, but also as between an overlying landowner and an appropriator. The overlying landowner in this state has been held to have analogous rights to those of a riparian. Such overlying landowner is now subject to the same restrictions as those applicable to riparian owners."

Apparently as between overlying landowners and appropriators from streams which feed the groundwater basin, the same rule applies as between riparian owners on a stream and appropriators from the stream. Presumably the overlying landowners could secure a declaratory judgment protecting them in their present and their prospective reasonable beneficial uses.

There is no general rule as to just what lowering of ground water constitutes an injury. It depends upon the facts in the case. A lowering of a given number of feet might be an injury in one case and not in another. Mere lowering of the water plane is not in itself a wrong.

Need for and Cost of Water in Santa Ana Basin

The plan for a transmountain diversion of Mojave River water to the Santa Ana Basin was occasioned by the alarm of irrigators and other water users in that basin over the persistent decline of the water levels in the wells from which most of their present supplies are pumped. The authors have felt no obligation to present an array of statistics or assorted statements of facts to establish the validity of this alarm, which they nevertheless believe to be justified. Santa Ana Basin is far from being unique with regard to the condition of its water table, for Mojave Valley is one of the few important places in California where pumping from wells is widely practiced that have not witnessed the same phenomenon in greater or less serious degree. Moreover, the fact that the decline of the water table has been arrested from time to time by temporarily

favorable seasons of high precipitation does not presage the eventual restoration of former water levels nor the establishment of a more stable regimen. Prophesy is likewise needless here as to when the economic limit of pumping lifts will be reached.

The generally admitted fact is that lifts are now so high as to involve pumping costs not supportable by any other agriculture than the citrus-walnut-avocado industry which typifies farming in Santa Ana Basin. Not for the purpose of expanding the present agricultural area, but to safeguard the already effected development an effort by Santa Ana water users to obtain a new supply is readily justifiable, provided the rights of other claimants are recognized and protected. In short, the statement of necessity included in the letter of April 17, 1935 to Secretary Wallace is considered to be generally correct.

However, even with the need for more water admitted, there is to be considered also the probable cost of obtaining it. The cost of water is only one of many costs entering into the production of crops, and it is not necessarily the controlling cost, notwithstanding the fact that water is the prime necessity of agriculture in southern California. Therefore, while the water cost which has been met heretofore does not have to be considered as the limit, and perhaps as a matter of salvage Santa Ana irrigators might pay substantially more for water than they have been paying, nevertheless returns from their industry above their total costs are certainly not so liberal as to justify a magnifying of the water cost, or any other cost for that matter.

The errand of the authors was not to ascertain the probable cost of the diversion, storage, and distributing works involved in the proposed transmountain plan. Rather, what they were concerned with in this phase of their study was a consideration of the cost which could be justified for that or any other plan involving the importation of water to Santa Ana Basin. One clue to this is the water costs now or recently carried by Orange County farmers, as tabulated by Harold E. Walberg, Farm Advisor for Orange County, in the "Report on Orchard Soil Management Course," May 7, 8, and 9, 1935, issued by the Los Angeles County Agricultural Extention Service. (See Table 50.) The costs listed do not include irrigation labor.

In explanation of the wide range of costs for the different crops, appearing in the final column of the table, Mr. Walberg says that, "the lemon and avocado orchards in this study generally are located on higher elevations where water is boosted once or twice, thus increasing costs. The low cost of water for walnuts is accounted for in the lower rates for gravity water in the winter season."

The unweighted average of the cost per acre-foot shown in Table 50 is $14.61.

TABLE 50. - Water usage and costs incurred by Orange County farmers, 1926-1934

Crop	Period	Average annual water usage per acre	Average cost per acre	Average cost per Ac.In.	Average cost per Ac.Ft.
	Years	Acre-inches	Dollars	Dollars	Dollars
Valencia oranges	9	19.4	14.31	0.74	8.85
Lemons	9	14.5	19.57	1.35	16.20
Walnuts	6	24.0	11.59	.48	5.79
Avocados	5	18.3	42.16	2.30	27.60

In point also are the 1929 figures in Table 51, which is made up of the averages reported in Table 5 of Bulletin No. 36, "Cost of Irrigation Water in California," Division of Water Resources, California State Department of Public Works, by Harry F. Blaney and M. R. Huberty.

TABLE 51. - Cost of water to irrigators, Mutual Water Companies, southern California, 1929

Company	Annual cost per acre-foot for average amount used	
	Excluding interest (6%) on value of capital stock	Including interest (6%) on value of capital stock
	Dollars	Dollars
Anaheim Union Water Company	9.38	12.93
Gage Canal Company	4.13	10.45
Riverside Water Company	3.14	9.92
San Antonio Water Company	9.21	18.41
Santa Ana Valley Irrigation Company	4.26	9.22
Temescal Water Company	11.34	16.52
Yorba Linda Water Company	13.95	16.65
Unweighted average	7.92	13.44

Domestic and industrial water rates run substantially higher than these costs, as shown below for the cities of San Bernardino, Riverside, and Santa Ana:

San Bernardino

Minimum meter rate per month

1/2 inch meter	....	$ 1.00	- 1,400 cu. ft.
3/4 inch meter	....	2.00	- 2,800 cu. ft.
1 inch meter	....	4.00	- 5,700 cu. ft.
1½ inch meter	....	6.00	- 8,500 cu. ft.
2 inch meter	....	8.00	- 11,400 cu. ft.
3 inch meter	....	12.00	- 17,100 cu. ft.
4 inch meter	....	16.00	- 22,800 cu. ft.
6 inch meter	....	24.00	- 34,200 cu. ft.

The following meter rates apply to consumption of water in excess of above amounts:

		Per 1000 Cu. Ft.
Less than	50,000 cubic feet	$0.70
50,000 to	60,000 cubic feet	.69
60,000 to	70,000 cubic feet	.68
70,000 to	80,000 cubic feet	.67
80,000 to	90,000 cubic feet	.66
90,000 to	100,000 cubic feet	.65
100,000 to	125,000 cubic feet	.64
125,000 to	150,000 cubic feet	.62
150,000 to	175,000 cubic feet	.59
175,000 to	200,000 cubic feet	.56
200,000 to	225,000 cubic feet	.53
225,000 to	250,000 cubic feet	.50
250,000 to	275,000 cubic feet	.47
275,000 to	750,000 cubic feet	.44
750,000 to	1,500,000 cubic feet	.41
1,500,000 to	3,000,000 cubic feet	.37
3,000,000 to	4,000,000 cubic feet	.34
4,000,000 to	6,000,000 cubic feet	.31
6,000,000 or	more	.26

Domestic meter rate. - For the first 1500 cubic feet, or less per month:

Through a	5/8	inch	meter	$1.50
" "	3/4	"	"	2.00
" "	1	"	"	2.50
" "	$1\frac{1}{2}$	"	"	3.25
" "	2	"	"	4.00
" "	3	"	"	6.00
" "	4	"	"	8.00

Add 50¢ to above for services outside of city limits.
For the first 2000 cubic feet per month in excess of the above minimum, 7¢ per 100 cubic feet.
In excess of 3500 cubic feet per month, 6¢ per 100 cubic feet.

Industrial meter rate. - For first 5000 cubic feet per month, same as domestic rates. In excess of 5000 cubic feet per month 5¢ per 100 cubic feet.

Riverside has also an acreage rate for a portion of the city formerly served by the Artesia Water Company. This is $7.00 per acre per year.

Santa Ana

Meter rates. -

For the first 4000 cu. ft. or less in any one month at the rate of 10 cents per 100 cu. ft.
For the next 21,000 cu. ft. at the rate of 8 cents per 100 cu. ft.
For the next 25,000 cu. ft. at the rate of 7 cents per 100 cu. ft. and all thereafter.

Monthly minimum meter rates:-

For each 5/8" or 3/4" Service	$1.00
For each 1" Service	1.25
For each $1\frac{1}{2}$" Service	2.25
For each 2" Service	3.25
For each 3" Service	4.75
For each 4" Service	7.25
For each 6" Service	9.75

The foregoing figures appear to indicate that, including capital charges, agricultural uses in Santa Ana Basin now support a cost of $10 to $15 per acre-foot for ~~imported~~ water, and that two or three times that amount is being met for water used for domestic and industrial purposes. Whether higher costs could be met would depend, of course, on degrees of necessity, or on changes in other costs affecting the agricultural and other industries of the Basin.

- APPENDIX -

TABLE A . - Assessed valuation of land along the Mojave River from the Forks to Newberry, listed as to school district and based on the 1934 San Bernardino County assessment

- - - - -

TOTAL ASSESSED VALUATION $562,847.

- - -

BIG BEAR LAKE

Sec.	6	T. 3 N - R. 3 W	$ 1,320.
"	7	" "	1,620.
"	18 & Pt.Sec.7	" "	850.

HESPERIA

Sec.	1	T. 3 N - R. 4 W	3,320.
"	12	" "	1,580.
"	13	" "	2,170.
"	1	T. 4 N - R. 4 W	5,890.
"	12	" "	3,200.
"	13	" "	2,000.
"	24	" "	1,540.
"	25	" "	1,540.
"	19	T. 4 N - R. 3 W	280.
"	30	" "	440.

APPLE VALLEY

Sec.	4	T. 4 N - R. 3 W	2,480.
"	5	" "	1,730.
"	6	" "	3,260.
"	7	" "	6,180.
"	8	" "	3,700.
"	9	" "	2,210.
"	16	" "	2,560.
"	17	" "	1,860.
"	18	" "	2,510.
"	19	" "	2,220.
"	20	" "	1,920.
"	30	" "	2,670.
"	31	" "	3,030.
"	30	T. 5 N - R. 3 W	4,060.
"	31	" "	7,120.
"	24	T. 5 N - R. 4 W	6,440.
"	25	" "	3,010.
"	36	" "	3,140.

VICTOR

Sec.	35	T. 5 N - R. 4 W	$ 3,570.
"	26	" "	4,160.
"	23	" "	5,070.
"	14	" "	7,810.
"	15	" "	7,270.
"	10	" "	280.
"	4	" "	240.
"	3	" "	1,700.
"	33	T. 6 N - R. 4 W	4,070.
"	32	" "	6,710.
"	29	" "	640.
"	30	" "	2,580.
"	31	" "	1,990.

ORO GRANDE

Sec.	6	T. 6 N - R. 4 W	1,450.
"	7	" "	2,580.
"	18	" "	5,470.
"	19	" "	6,600.
"	20	" "	290.
"	29	" "	2,950.
"	30	" "	3,690.
"	1	T. 6 N - R. 5 W	5,330.
"	12	" "	3,080.
"	18	T. 7 N - R. 4 W	5,510.
"	19	" "	6,450.
"	13	T. 6 N - R. 5 W	1,710.
"	24	" "	2,370.
"	30	T. 7 N - R. 4 W	2,390.
"	31	" "	1,660.
"	13	T. 7 N - R. 5 W	1,590.
"	24	" "	2,000.
"	25	" "	5,980.
"	36	" "	6,260.

HELENDALE

Sec.	6	T. 7 N - R. 4 W	6,910.
"	7	" "	7,690.
"	1	T. 7 N - R. 5 W	2,270.
"	12	" "	880.
"	31	T. 8 N - R. 4 W	4,240.
"	32	" "	1,080.
"	30	" "	4,390.
"	29	" "	990.
"	19	" "	1,050.
"	20	" "	4,480.
"	17	" "	560.
"	16	" "	2,110.
"	15	" "	4,600.
"	14	T. 8 N - R. 4 W	3,110.
"	10	" "	3,070.
"	11	" "	4,380.
"	12	" "	4,170.
"	1	" "	660.

TABLE A . - Contd.

HODGE

Sec. 6	T. 8 N - R. 3 W	$ 790.
" 7	" "	1,930.
" 5	" "	1,497.
" 4	" "	2,390.
" 33	T. 9 N - R. 3 W	1,020.
" 28	" "	700.
" 27	" "	4,020.
" 22	T. 9 N - R. 3 W	2,050.
" 23	" "	1,840.
" 15	" "	1,860.
" 14	" "	1,830.

HINKLEY

Sec. 11	T. 9 N - R. 3 W	2,400.
" 10	" "	1,310.
" 2	" "	5,110.
" 3	" "	2,000.
" 35	T.10 N - R. 3 W	6,800.
" 34	" "	3,590.
" 28	" "	8,750.
" 27	" "	6,500.
" 26	" "	7,660.
" 23	T.10 N - R. 3 W	5,290.
" 22	" "	5,490.
" 15	" "	2,530.
" 14	" "	2,470.
" 11	" "	1,920.
" 10	" "	1,920.

TODD

Sec. 1	T. 9 N - R. 3 W	2,110.
" 12	" "	1,210.
" 13	" "	1,600
" 24	" "	2,440.
" 3	T. 9 N - R. 2 W	1,760.
" 4	" "	5,510.
" 5	" "	3,170.
" 6	T. 9 N - R. 2 W	3,170.
" 7	" "	2,160.
" 8	" "	1,760.
" 9	" "	1,840.
" 18	" "	3,130.
" 19	" "	3,400.
" 36	T.10 N - R. 3 W	6,860.
" 25	" "	6,780.
" 24	" "	2,110.
" 29	T.10 N - R. 2 W	1,230.
" 30	" "	4,890.
" 31	" "	4,320.
" 32	" "	3,360.
" 33	" "	3,990.

TABLE A . - Contd.

BARSTOW

Sec.	1	T. 9 N - R. 2 W	$ 3,310.
"	2	" "	2,150.
"	3	" "	1,180.
"	10	" "	690.
"	31	T.10 N - R. 1 W	8,260.
"	32	T.10 N - R. 1 W	3,450.
"	33	" "	1,540.
"	3	T. 9 N - R. 1 W	820.
"	4	" "	1,600.
"	5	" "	740.
"	9	" "	820.
"	10	" "	2,210.
"	11	" "	1,250.
"	12	T. 9 N - R. 1 W	480.
"	13	" "	600.

DAGGETT

Sec.	10	T. 9 N - R. 1 E	1,280.
"	11	" "	1,200.
"	14	" "	1,380.
"	15	" "	1,620.
"	16	" "	1,290.
"	17	T. 9 N - R. 1 E	1,300.
"	18	" "	1,340.
"	20	" "	710.
"	21	" "	2,180.
"	22	" "	1,980.

YERMO

Sec.	12	T. 9 N - R. 1 E	780.
"	1	T. 9 N - R. 2 E	920.
"	3	" "	1,280.
"	4	" "	1,920.
"	5	" "	2,520.
"	6	" "	1,080.
"	36	T.10 N - R. 2 E	1,540.
"	35	" "	1,830.
"	24	T.10 N - R. 3 E	470.
"	26	" "	200.
"	27	" "	1,650.
"	28	" "	260.
"	29	T.10 N - R. 3 E	1,540.
"	20	T.10 N - R. 4 E	220.
"	19	" "	1,090

FAIRVIEW

Sec.	25	T.10 N - R. 3 E	2,260.
"	26	" "	1,360.
"	36	" "	2,740.
"	35	" "	1,910.
"	34	T.10 N - R. 3 E	520.
"	33	" "	1,790.
"	32	" "	480.

FAIRVIEW (Cont'd)

Sec.	30	T. 10 N - R. 4 E	$ 760.
"	31	" "	820.
"	1	T. 9 N - R. 3 E	1,820.
"	2	" "	960.
"	3	" "	960.
"	4	" "	620.
"	5	" "	2,000.
"	7	" "	2,040.
"	8	" "	320.
"	9	" "	2,560.
"	10	" "	1,560.
"	11	T. 9 N - R. 3 E.	2,240.
"	12	" "	2,360.
"	13	" "	2,140.
"	14	" "	2,680.
"	15	" "	2,000.
"	16	T. 9 N - R. 3 E	1,920.
"	17	" "	2,560.
"	19	" "	630.
"	21	" "	2,210.
"	22	" "	1,020.
"	23	" "	380.
"	27	" "	1,790.
"	28	T. 9 N - R. 3 E	1,020.
"	29	" "	2,050.
"	30	" "	380.
"	32	" "	2,830.
"	6	T. 9 N - R. 4 E	990.
"	7	"	1,530.

MINNEOLA

Sec.	2	T. 9 N - R. 2 E	590.
"	3	" "	1,390.
"	4	" "	640.
"	7	" "	640.
"	8	" "	1,220.
"	9	" "	2,560.
"	10	" "	1,400.
"	11	" "	1,110.
"	12	T. 9 N - R. 2 E	1,520.
"	13	" "	2,560.
"	14	" "	1,800.
"	15	" "	1,280.
"	16	" "	2,560.
"	17	" "	1,540.
"	18	" "	2,040.
"	19	" "	1,240.
"	20	" "	2,560.
"	21	T. 9 N - R. 2 E	1,540.
"	22	" "	2,000.
"	23	" "	1,640.
"	25	" "	2,460.
"	26	" "	320.
"	27	" "	1,690.
"	28	" "	1,280.
"	29	" "	1,970.

TABLE B. - Records of water levels at typical wells in the Upper Mojave Valley along the river. (See Plate 5A in Appendix.)

Well No. U-1 Owner: Olive, (formerly West)

Location and description: Southeast corner of NW$\frac{1}{4}$ of NE$\frac{1}{4}$, Sec. 13, T. 3 N., R. 4 W. S.B.B. & M. On top of bluff at west side of road from West Fork saddle to bottom of McInnis crossing.
Use: Domestic.
Reference point: Top of 2" x 12" board cover on well at ground level.
Elevation of reference point ("R.P."): 3012.5 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
May 15, 1922	69.8 1/	Apr. 21, 1930	78.7	Feb. 20, 1932	80.1
Jan. 11, 1923	68.6 1/	Dec. 11, 1930	81.0	Mar. 18, 1932	79.3
Sept. 27, 1923	71.9 1/	Jan. 27, 1931	79.8	June 9, 1932	77.9
Oct. 18, 1923	69.7 1/	Mar. 4, 1931	79.0	Aug. 9, 1932	78.8
Dec. 6, 1929	84.9	May 1, 1931	78.0	Nov. 3, 1932	84.8
Mar. 5, 1930	80.5	Nov. 13, 1931	88.7	Dec. 14, 1933	89.7
Apr. 1, 1930	79.3	Jan. 7, 1932	81.9	Jan. 16, 1935	82.0

1/ Measurement from W. P. Rowe.

Well No. U-4

Location and description: Near center of SE$\frac{1}{4}$, Sec. 12, T. 3 N., R. 4 W., S. B. B. & M. On west side of Mojave River just above McInnis crossing.
Use: Stock windmill.
Reference point: Top of 2" x 12" cover on concrete pit 36 inches in diameter.
Elevation of reference point ("R.P."); 2955.4 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
Dec. 6, 1929	25.9 dry	Jan. 27, 1931	14.3	Jan. 7, 1932	8.8
Mar. 8, 1930	8.4	Feb. 20, 1931	8.6	Feb. 20, 1932	7.6
Apr. 1, 1930	8.3	Mar. 4, 1931	8.7	Mar. 18, 1932	7.8
Apr. 12, 1930	8.1	May 1, 1931	8.4	June 9, 1932	7.5
Apr. 21, 1930	8.5	Aug. 4, 1931	20.8	Aug. 9, 1932	14.9
Dec. 11, 1930	15.1	Oct. 1, 1931	27. dry	Nov. 3, 1932	25. dry
				Jan. 16, 1935	8.3

TABLE B. - Contd.

Well U-9

Location and description: Near northeast corner of $S\frac{1}{4}$ of $NW\frac{1}{4}$, Sec. 30, T. 4 N., R. 3 W., S.B.B. & M.
Use: Irrigation.
Reference point: Top of 5 foot concrete pit curb at ground surface on north side.
Elevation of reference point ("R.P."): 2897.3 feet.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Mar. 6, 1917	32.8 1/	Apr. 21, 1930	42.1	Feb. 20, 1932	45.1
Jan. 18, 1930	45.6	Apr. 30, 1930	41.2	Mar. 18, 1932	40.2
Mar. 5, 1930	46.0	Jan. 25, 1931	45.2	June 2, 1932	37.0
Mar. 17, 1930	45.8	Feb. 12, 1931	44.5	Aug. 9, 1932	38.0
Mar. 22, 1930	45.7	Mar. 3, 1931	44.5	Nov. 3, 1932	40.0
Apr. 1, 1930	44.2	May 1, 1931	45.1	May 17, 1934	44.8
Apr. 14, 1930	42.1	July 28, 1931	45.8	Jan. 24, 1935	47.0
				Apr. 16, 1935	39.2

1/Mojave River Commission Report.

Well No. U-13

Location and description: Near center of west line of $SE\frac{1}{4}$ of $SE\frac{1}{4}$, Sec. 19, T. 4 N., R. 3 W., S.B.B. & M.
Use: Test well.
Reference point: Top of 2 inch pipe under coupling and plug 0.5 foot above ground level.
Elevation of reference point ("R.P."): 2890.2 feet.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Jan. 28, 1905	39.6 1/	Feb. 20, 1931	37.4	Nov. 3, 1932	30.9
June 12, 1907	10.8 1/	May 1, 1931	38.5	Mar. 3, 1933	35.6
Mar. 5, 1930	39.4	July 28, 1931	38.6	Apr. 18, 1933	23.6
Mar. 17, 1930	39.6	Nov. 13, 1931	40.4	Dec. 14, 1933	36.7
Mar. 22, 1930	39.5	Jan. 15, 1932	41.0	May 17, 1934	35.6
Apr. 1, 1930	33.4	Feb. 19, 1932	30.4	Jan. 7, 1935	42.1
Apr. 8, 1930	29.7	Mar. 18, 1932	22.5	Jan. 24, 1935	38.6
Apr. 14, 1930	27.6	Apr. 19, 1932	18.0	Feb. 7, 1935	37.1
Apr. 21, 1930	27.1	May 5, 1932	16.6	Feb. 12, 1935	32.5
Apr. 30, 1930	28.1	May 13, 1932	16.0	Feb. 27, 1935	26.8
May 12, 1930	24.7	May 26, 1932	15.2	Mar. 13, 1935	24.1
Dec. 11, 1930	35.3	June 2, 1932	16.0	Apr. 16, 1935	18.7
Jan. 28, 1931	36.9	July 15, 1932	22.6	May 8, 1935	17.1
Feb. 12, 1931	37.2	Sept. 7, 1932	27.5		

1/ Lowest and highest observations (Jan. 1905 - Dec. 1920) from records of Arrowhead Reservoir and Power Company. Test well No. 1.

TABLE B . - Contd.

Well No. U-17 Owner: W. O. Wade

Location and description: In southwest corner of NE$\frac{1}{4}$ of NE$\frac{1}{4}$, Sec. 21, T. 4 N., R. 3 W., S.B.B. & M.
Use: Not used.
Reference point: Top of curb at ground level.
Elevation of reference point ("R.P."): 3100.5 feet.

Date	Dist.R.P. to water surface (Feet)	Date	Dist.R.P. to water surface (Feet)	Date	Dist.R.P. to water surface (Feet)
Mar. 1, 1917	242.0 1/	Aug. 4, 1931	257.2	Sept. 13, 1932	253.0
Jan. 9, 1923	247.6 2/	Jan. 20, 1932	258.0	Mar. 2, 1933	254.6
Jan. 31, 1930	255.7	Mar. 25, 1932	256.8	Dec. 21, 1933	255.4
Dec. 17, 1930	255.0	Apr. 29, 1932	255.6	May 17, 1934	256.5
Mar. 10, 1931	255.7	June 2, 1932	254.1	Jan. 24, 1935	258.6
May 11, 1931	256.6	July 20, 1932	253.0	May 8, 1935	255.3

1/ Mojave River Commission Report.
2/ Measurement from W. P. Rowe.

Well No. U-43 Owner: A. W. Phillips

Location and description: Near northeast corner of NW$\frac{1}{4}$ of NW$\frac{1}{4}$, Sec. 6, T. 4 N. R. 3 W., S.B.B. & M.
Use: Domestic.
Reference point: Crack in windmill foundation 0.5 foot above concrete block at casing level and 1.5 feet above ground.
Elevation of reference point ("R.P."): 2873.0 feet.

Date	Dist.R.P. to water surface (Feet)	Date	Dist.R.P. to water surface (Feet)	Date	Dist.R.P. to water surface (Feet)
Feb. 24, 1917	51.5 1/	Nov. 18, 1931	57.7	Oct. 8, 1932	56.2
Jan. 25, 1930	56.3	Jan. 7, 1932	57.3	Nov. 3, 1932	55.8
Jan. 26, 1931	56.2	Feb. 19, 1932	56.9	Dec. 21, 1933	56.3
Feb. 17, 1931	56.1	May 27, 1932	56.3 2/	May 17, 1934	57.6 2/
May 7, 1931	56.8	July 20, 1932	56.2	Jan. 16, 1935	57.4
July 28, 1931	59.0 2/	Sept. 13, 1932	56.3	May 8, 1935	55.7
				May 22, 1935	55.5

1/ Mojave River Commission Report.

2/ Windmill pumping.

TABLE B . - Contd.

Well No. U-57

Location and description: In $NW\frac{1}{4}$, Sec. 18, T. 5 N., R. 3 W., S.B.B. & M. In old pumphouse.
Reference point: Top of broken concrete pipe 1.0 foot above ground and 7.25 feet above top of steel casing.
Elevation of reference point ("R.P."): 2910.4 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Feb. 27, 1917	98.0 1/	Jan. 30, 1931	106.7	Apr. 29, 1932	106.7
Feb. 13, 1923	104.2 2/	May 15, 1931	107.5	July 28, 1932	106.6
Jan. 25, 1930	106.7	Aug. 3, 1931	107.9	Mar. 2, 1933	106.4
				Feb. 21, 1935	107.5

1/ Mojave River Commission Report.
2/ Measurement from W. P. Rowe.

Well No. U-59 Owner: Lee Saul

Location and description: 1000 feet northwest of $S\frac{1}{4}$ corner of Sec. 11, T. 5 N., R. 4 W., S.B.B. & M.
Use: Domestic.
Reference point: Top of 8 inch O.D. casing 2.6 feet above ground.
Elevation of reference point ("R.P."): 2788.3 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Jan. 30, 1931	56.4	July 28, 1931	56.1	June 15, 1932	55.2
Feb. 14, 1931	55.8	Nov. 12, 1931	55.9	May 8, 1935	55.4
May 14, 1931	55.8	Mar. 22, 1932	55.3		

TABLE B . - Contd.

Well No. U-72

Location and description: Near southwest corner of Sec. 36, T. 5 N., R. 4 W., S.B.B. & M.
Use: Irrigation.
Reference point: Top 2-inch wood curb on west side of pit 0.2 foot above ground.
Elevation of reference point ("R.P."): 2824.8 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Apr. 12, 1917	4.0 1/	May 2, 1931	9.4	Apr. 29, 1932	6.0
Feb. 1, 1930	6.3	Aug. 4, 1931	10.6	Sept. 13, 1932	7.8
Apr. 3, 1930	6.6	Oct. 8, 1931	8.5	May 24, 1933	5.3
Jan. 28, 1931	8.4	Nov. 12, 1931	8,0	Dec. 21, 1933	6.2
Feb. 14, 1931	8.4	Jan. 7, 1932	7.4	May 17, 1934	6.9
Feb. 20, 1931	8.3	Feb. 24, 1932	5.8	May 22, 1935	5.5

1/ Mojave River Commission Report.

TABLE C . - Records of water levels at typical wells in the Middle Mojave Valley along the river. (See Plate 5B in Appendix.)

Well No. M-3 Owner: John Bennette

Location and description: In $SW\frac{1}{4}$ of $NE\frac{1}{4}$, Sec. 19, T. 6 N., R. 4 W., S.B.B. & M. Near water tank south of cottages.
Use: Domestic.
Reference point: Top of 1-inch well curb at ladder 2.5 feet above ground.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Sept. 4, 1930	19.9	Nov. 12, 1931	18.1 1/	Sept. 7, 1932	19.8
Dec. 12, 1930	18.3	Jan. 14, 1932	19.0 1/	Jan. 10, 1934	18.6
May 20, 1931	18.9 1/	Feb. 23, 1932	20.8 1/	Jan. 21, 1935	18.4
Aug. 5, 1931	19.4	June 1, 1932	22.4 1/		

1/ Windmill pumping slowly.

Well No. M-15

Location and description: In southeast corner of Sec. 31, T. 8 N., R. 4 W., S.B.B. & M.
Use: Not used.
Reference point: Top of concrete curb under two railroad ties which is 10.71 feet above top of 14-inch casing in pit.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Sept. 5, 1930	16.9	Oct. 2, 1931	16.0	June 23, 1932	15.0
Dec. 13, 1930	15.0	Nov. 5, 1931	15.4	Sept. 7, 1932	16.1
Mar. 20, 1931	14.5	Jan. 7, 1932	14.8	Jan. 10, 1934	15.0
May 20, 1931	14.8	Feb. 23, 1932	14.4	Jan. 21, 1935	15.0
Aug. 4, 1931	15.9	Mar. 23, 1932	14.4		

TABLE C . - Contd.

Well No. M-40 Owner: L. S. Emerson

Location and description: In SW¼ of SW¼, Sec. 34, T. 9 N., R. 3 W., S.B.B. & M. Pumping plant at south edge of highway.
Use: Irrigation.
Reference point: Three notches in timber at ground level in northwest corner of pit.
Elevation of reference point ("R.P."): 2273.4 feet.

Date	Dist. R.P. of water surface (Feet)	Date	Dist. R.P. of water surface (Feet)	Date	Dist. R.P. of water surface (Feet)
Jan. 15, 1919	16.1 1/	Aug. 5, 1931	15.6	May 18, 1932	12.0
Jan. 14, 1923	13.1 2/	Oct. 7, 1931	16.9	Sept.23, 1932	14.8
Jan. 24, 1930	16.5	Nov. 17, 1931	17.3	Nov. 15, 1932	15.5
Sept. 11, 1930	15.5	Dec. 23, 1931	17.1	Mar. 2, 1933	12.5
Dec. 12, 1930	16.7	Feb. 15, 1932	12.6	Dec. 14, 1933	16.8
Feb. 13, 1931	14.7	Feb. 23, 1932	12.9	Jan. 7, 1935 3/	17.0
Mar. 17, 1931	13.5	Mar. 17, 1932	12.0	Jan. 21, 1935	16.9
May 6, 1931	13.9	Apr. 6, 1932	11.9	Feb. 8, 1935 3/	15.0
				Apr. 17, 1935	12.4

1/ Measurement from W.S. Paper 578, page 435, Well 79.
2/ Measurement from W. P. Rowe.
3/ River flows on surface west of well about first of each year.

Well No. 51 Owner: J. Slagill

Location and description: In NE¼ of NE¼, Sec. 28, T. 9 N., R. 3 W. S.B.B. & M. At edge of river.
Use: Domestic.
Reference point: Top of 1-inch cover of pit at ground level. Casing in bottom of pit.

Date	Dist. R.P. of water surface (Feet)	Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)
Sept. 11, 1930	17.0	Oct. 7, 1931	22.2	Mar. 4, 1932	3.4
Feb. 13, 1931	6.7	Dec. 23, 1931	22.5	Jan. 10, 1933	11.4
Mar. 17, 1931	4.6	Jan. 7, 1932	20.4	Feb. 9, 1934	4.3
Aug. 5, 1931	20.2	Feb. 4, 1932	14.5	Jan. 7, 1935	21.9
				Feb. 8, 1935	6.2

TABLE C . - Contd.

Well No. M-52

Location and description: In SE¼ of SW¼, Sec. 10, T. 9 N., R. 3 W., S.B.B.& M. On hill.
Use: Not used.
Reference point: Small hole punched in west side of casing, 0.5 foot above ground.
Elevation of reference point ("R.P."): 2292.2 feet.

Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)
Apr. 4, 1930	90.8	Mar. 29, 1932	91.7	Jan. 7, 1935	91.4
Feb. 25, 1931	91.4	July 26, 1932	91.7	Jan. 21, 1935	91.4
Aug. 6, 1931	91.4	Dec. 22, 1932	91.5	Feb. 8, 1935	91.5
Mar. 10, 1932	91.7	Feb. 9, 1934	91.1		

Well No. M-56-A Owner: Bullock

Location and description: In southwest corner of NW¼ of NW¼, Sec. 14, T. 9 N., R. 3 W., S.B.B. & M. At pumping plant on east side of road.
Reference point: Top of 2-inch well cover at ground.
Elevation of reference point ("R.P."): 2213.9 feet.

Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)
Dec. 19, 1930	23.8	Mar. 29, 1932	16.0	Jan. 7, 1935	23.9
Mar. 17, 1931	24.4	July 26, 1932	13.0	Feb. 8, 1935	23.8
Aug. 5, 1931	24.9	Oct. 5, 1932	14.2	Apr. 1, 1935	22.3
Feb. 4, 1932	25.0	Dec. 22, 1932	16.0	Apr. 17, 1935	18.3
Mar. 4, 1932	17.3	Jan. 10, 1934	19.7	Apr. 23, 1935	17.8

TABLE C . - Contd.

Well No. M-57-A

Location and description: In northeast corner of $SE\frac{1}{4}$ of $SE\frac{1}{4}$, Sec. 15, T.9 N., R. 3 W., S.B.B. & M. On west side of road at edge of river.
Reference point: Top of 12-inch casing near 30-inch casing, 3.0 feet below ground.
Elevation of reference point ("R.P."): 2217.9 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
Dec. 19, 1930	17.9	Feb. 4, 1932	18.4	July 26, 1932	6.2
Mar. 17, 1931	18.5	Mar. 4, 1932	3.8	Jan. 7, 1935	18.8
Aug. 5, 1931	19.1	Mar. 29, 1932	2.6	Feb. 8, 1935	19.1
				Apr. 17, 1935	7.4

Well No. M-66

Location and description: Near center of south line of $SE\frac{1}{4}$ of $NW\frac{1}{4}$, Sec. 34, T. 11 N., R. 3 W., S.B.B. & M. 0.6 mile north of south line of Sec. 34 in galvanized pump house with cottonwoods 300 feet east of road.
Use: Not used.
Reference point: Top of 12" x 12" timber across pit, 1.5 feet above curb top at ground level.
Elevation of reference point ("R.P."): 2086.9 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
May 31, 1930	29.5	Mar. 10, 1932	30.0	Feb. 9, 1934	30.2
Feb. 25, 1931	29.7	Mar. 29, 1932	29.9	Mar. 1, 1935	30.5
Aug. 27, 1931	29.7	Dec. 22, 1932	30.0		

TABLE C . - Contd.

Well No. M-71 Owner: A. H. Harris

Location and description: Near southwest corner of Sec. 23, T. 10 N., R. 3 W., S.B.B. & M. North of rock hill and east of road.
Reference point: Top of railroad tie at ground level on east side of curb.
Elevation of reference point ("R.P."): 2163.7 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
Sept. 19, 1930	26.9	Aug. 11, 1931	28.0	Dec. 22, 1932	28.5
Dec. 19, 1930	26.9	Mar. 10, 1932	28.0	Mar. 1, 1935	30.7
June 4, 1931	27.4	Mar. 29, 1932	28.2		

Well No. M-74 Owner: J. D. Rich

Location and description: In southeast corner of SW¼ of SW¼, Sec. 30, T. 10 N., R. 2 W., S.B.B. & M.
Use: Domestic.
Reference point: Top of wood clamp 0.47 foot above top of cement pipe casing which is 1.5 feet above ground.
Elevation of reference point ("R.P."): 2179.0 feet.

Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface	Date	Dist.R.P. to water surface
	Feet		Feet		Feet
Apr. 4, 1930	20.1	Nov. 17, 1931	22.4	May 12, 1932	21.8 1/
Dec. 19, 1930	20.8	Mar. 4, 1932	21.4	July 6, 1932	25.1 2/
Mar. 27, 1931	21.6	Mar. 29, 1932	21.9 1/	Jan. 11, 1933	20.6
Aug. 13, 1931	22.3	Apr. 21, 1932	22.4 1/	Jan. 10, 1934	20.9
				Jan. 21, 1935	21.6

1/ Pumping nearby.
2/ Windmill pumping slowly.

TABLE C. Contd.

Well No. M-85 Owner: E. M. Hawes

Location and description: In southeast corner of $NE\frac{1}{4}$, Sec. 31, T. 10 N., R. 1 W., S. B. B. & M. Across from old Chas. Mitchel house.
Use: Domestic.
Reference point: Top of 2-inch clamp on cylinder at average ground level.
Elevation of reference point ("R.P."): 2094.1 feet.

Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)
Oct. 20, 1919	11.6 1/	Aug. 13, 1931	12.7	May 10, 1932	8.3
Apr. 4, 1930	10.0	Oct. 7, 1931	12.7	Aug. 8, 1932	10.6
Dec. 19, 1930	11.5 2/	Mar. 17, 1932	9.0	Nov. 15, 1932	10.4
May 7, 1931	11.9	Apr. 27, 1932	8.4	Jan. 23, 1934	10.2

1/ Measurement from W.S. Paper 578, page 435, Well 60.
2/ Pumping 300 feet south.

TABLE D. - Records of water levels at typical wells in the Lower Mojave Valley along the river. (See Plate 5C in Appendix.)

Well No. M-92 Owner: Gibbs

Location and description: In $NE\frac{1}{4}$ of $NE\frac{1}{4}$, Sec. 10, T. 9 N., R. 1 W., S.B.B. & M. About 200 feet south of house.
Use: Irrigation.
Reference point: Top of square wood curb in underground house for pump. 7.3 feet below cover on pit.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Sept. 12, 1925	10. 1/	Jan. 21, 1931	10.2	Nov. 15, 1932	5.1
Oct. 11, 1927	4.7 1/	Nov. 24, 1931	10.7	Feb. 15, 1935	10.4
Oct. 6, 1928	7.8 1/	Mar. 23, 1932	5.2	May 29, 1935	10.9
May 30, 1930	9.9	May 26, 1932	3.2		

1/ Measurement from W. P. Rowe.

Well No. L-1 Owner: B. A. Funk

Location and description: Southwest corner of $NW\frac{1}{4}$, Sec. 18, T. 9 N., R. 1 E., S.B.B. & M. South side of Van Dyke Ditch above Greer's ranch.
Use: Irrigation.
Reference point: Top of 4" x 6" well curb on south side at average ground level.
Elevation of reference point ("R.P."): 1996.8 feet.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Sept. 12, 1925	25.8 1/	Jan. 20, 1930	29.6	Jan. 21, 1931	30.8
Mar. 21, 1926	26.0 1/	Feb. 21, 1930	30.0	Apr. 23, 1931	32.3
Feb. 16, 1927	20.0 1/	Feb. 27, 1930	30.0	Aug. 12, 1931	33.2
May 12, 1927	10.3 1/	Mar. 7, 1930	30.0	Nov. 23, 1931	33.7
June 22, 1927	10.8 1/	Mar. 19, 1930	30.1	Feb. 16, 1932	25.9
Oct. 11, 1927	15.2 1/	Apr. 16, 1930	32.0	Apr. 6, 1932	11.4
Nov. 23, 1928	25.8 1/	May 7, 1930	30.8	Mar. 30, 1934	24.9
Dec. 12, 1928	25.8 1/	May 29, 1930	30.8	Jan. 22, 1935	29.9
				May 29, 1935	31.4

1/ Measurement from W. P. Rowe.

TABLE D. - Contd.

Well No. L-16 A　　　　Owner: Edwards

Location and description: Near center of west line of NW¼, Sec. 19, T. 9 N., R. 3 E., S.B.B. & M.
Use: Old Edwards well to irrigate beyond dunes.
Reference point: Top of 12 inch casing.
Elevation of reference point ("R.P."): 1860.1 feet.

Date	:Dist.R.P.: :to water : : surface : Feet	Date	:Dist.R.P.: :to water : : surface : Feet	Date	:Dist.R.P. :to water : surface Feet
May 22, 1922	Flowing 1/	Jan. 22, 1931	1.8	Apr. 27, 1932	2.0
May 8, 1930	1.4	May 7, 1931	2.4	July 13, 1932	2.4
May 22, 1930	1.5	Feb. 26, 1932	2.2	Jan. 30, 1935	3.6

1/ Measurement from W. P. Rowe.

Well No. L-19　　　　Owner: Klinkenbeard

Location and description: In northwest corner of NW¼, Sec. 34, T. 9 N., R. 3 E., S.B.B. & M.
Reference point: Top of wood curb 0.3 foot above well cover which is at ground level.
Elevation of reference point ("R.P."): 1827.9 feet.

Date	:Dist.R.P.: :to water : : surface : Feet	Date	:Dist.R.P.: :to water : : surface : Feet	Date	:Dist.R.P. :to water : surface Feet
Nov. 18, 1919	29.4 1/	Feb. 28, 1930	28.2	Apr. 27, 1932	28.5
May 22, 1922	29.2 2/	Mar. 23, 1932	28.6	Feb. 14, 1934	29.2

1/ Measurement from W.S. Paper 578, page 469, Well 111, corrected for change in reference point.
2/ Measurement from W. P. Rowe.

TABLE D. - Contd.

Well No. L-20 Owner: Dr. Lyle Graham

Location and description: Near northwest corner of $NE\frac{1}{4}$, Sec. 4, T. 8 N. R. 3 E., S.B.B. & M. At northeast corner of reservoir. 10 feet west of L-21.
Use: Irrigation.
Reference point: Top of 3-foot concrete curb.
Elevation of reference point ("R.P."): 1821.4 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Apr. 15, 1930	Flowing	Dec. 7, 1931	Flowing	Apr. 28, 1932	Flowing
June 5, 1931	Flowing	Feb. 26, 1932	Flowing	Feb. 15, 1933	Flowing
				Jan. 30, 1935	Flowing

Well No. L-42 Owner: G. Linquenfelder

Location and description: Near center of $SW\frac{1}{4}$, Sec. 15, T. 9 N., R. 1 E., S.B.B. & M. North of Van Dyke's house on flat.
Reference point: Top concrete slab at ground surface, west side of well, 5.9 feet above 12-inch casing in pit.
Elevation of reference point ("R.P."): 1963.7 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Aug. 14, 1925	69.2 1/	Feb. 1, 1930	74.4	Feb. 27, 1932	77.5
Apr. 15, 1926	71.9 1/	May 23, 1930	75.2	Mar. 24, 1932	73.6
Feb. 16, 1927	74.2 1/	Apr. 22, 1931	77.8	Jan. 25, 1934	75.8
Oct. 10, 1927	69.5 1/	Dec. 7, 1931	79.1	Jan. 22, 1935	79.2
Oct. 21, 1928	70.7 1/	Feb. 16, 1932	79.2	May 29, 1935	80.3

1/ Measurement from W. P. Rowe.

TABLE D. - Contd.

Well No. L-51 Owner: McCormick

Location and description: Near center of $NE\frac{1}{4}$, Sec. 3, T. 9 N., R. 2 E., S.B.B. & M. East of house and mill near steam boiler.
Use: Domestic.
Reference point: Top of 12 inch casing at hand pump. 0.9 foot above ground.
Elevation of reference point ("R.P."): 1844.0 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Nov. 1, 1919	13.3 1/	Jan. 22, 1931	19.0	Jan. 11, 1933	18.6
May 17, 1922	5.5 2/	Sept. 24, 1931	20.2	Jan. 23, 1934	20.5
Dec. 15, 1922	6.6 2/	Jan. 21, 1932	19.5	Jan. 30, 1935	21.9
May 23, 1930	16.5	Apr. 27, 1932	16.7		

1/ Measurement from W.S. Paper 578, page 467, Well 55a, corrected for change in reference point.
2/ Measurement from W. P. Rowe.

Well No. L-52 Owner: Fisher

Location and description: In northwest corner of $SE\frac{1}{4}$, Sec. 3, T. 9 N., R. 2 E., S.B.B. & M. 100 feet northwest of house. Old three leg steel tower, no mill.
Use: Domestic.
Reference point: Top of steel cover on 10-inch casing, 1.3 feet above ground.
Elevation of reference point ("R.P."): 1859.4 feet.

Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet	Date	Dist. R.P. to water surface Feet
Feb. 20, 1930	5.5	Jan. 22, 1931	5.9	Apr. 27, 1932	6.2
May 23, 1930	6.3	Sept. 24, 1931	7.9	Jan. 11, 1933	6.4
				Jan. 29, 1935	6.7

TABLE D . - Contd.

Well No. L-63

Location and description: Near center of Sec. 18, T. 9 N., R 2 E., S.B.B. & M. Corner of Soap Ranch.
Reference point: Top of 12-inch casing 1.0 foot above ground.
Elevation of reference point ("R.P."); 1934.7 feet.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
June 13, 1924	48.0 1/	Feb. 28, 1930	56.7	Nov. 2, 1932	57.5
Sept. 13, 1925	52.0 1/	May 8, 1930	57.1	Jan. 11, 1933	57.8
Mar. 15, 1926	50.3 1/	Jan. 22, 1931	58.2	Jan. 23, 1934	59.2
Mar. 3, 1927	52.5 1/	Mar. 17, 1932	58.5	Jan. 22, 1935	60.7
Sept. 12, 1928	54.1 1/	Apr. 21, 1932	57.4	May 29, 1935	61.2

1/ Measurement from W. P. Rowe.

Well No. L-68-A Owner: Scobel & Haimut

Location and description: In SW¼ Sec. 14, T. 9 N., R. 2 E., S.B.B. & M. Northeast of L-68.
Reference point: Top of casing at ground.
Elevation to reference point ("R.P."): 1886.0 feet.

Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet	Date	Dist.R.P. to water surface Feet
Nov. 10, 1925	15.8 1/	Oct. 9, 1930	19.0	Jan. 11, 1933	19.8
Mar. 7, 1927	16.6 1/	Aug. 26, 1931	22.8 2/	Feb. 14, 1934	20.8
Sept. 12, 1928	20.3 1/	Jan. 28, 1932	20.2	Jan. 30, 1935	21.5
Feb. 28, 1930	21.1	Mar. 17, 1932	22.6 2/	May 29, 1935	24.7 2/

1/ Measurement from W. P. Rowe.
2/ Pumping nearby.

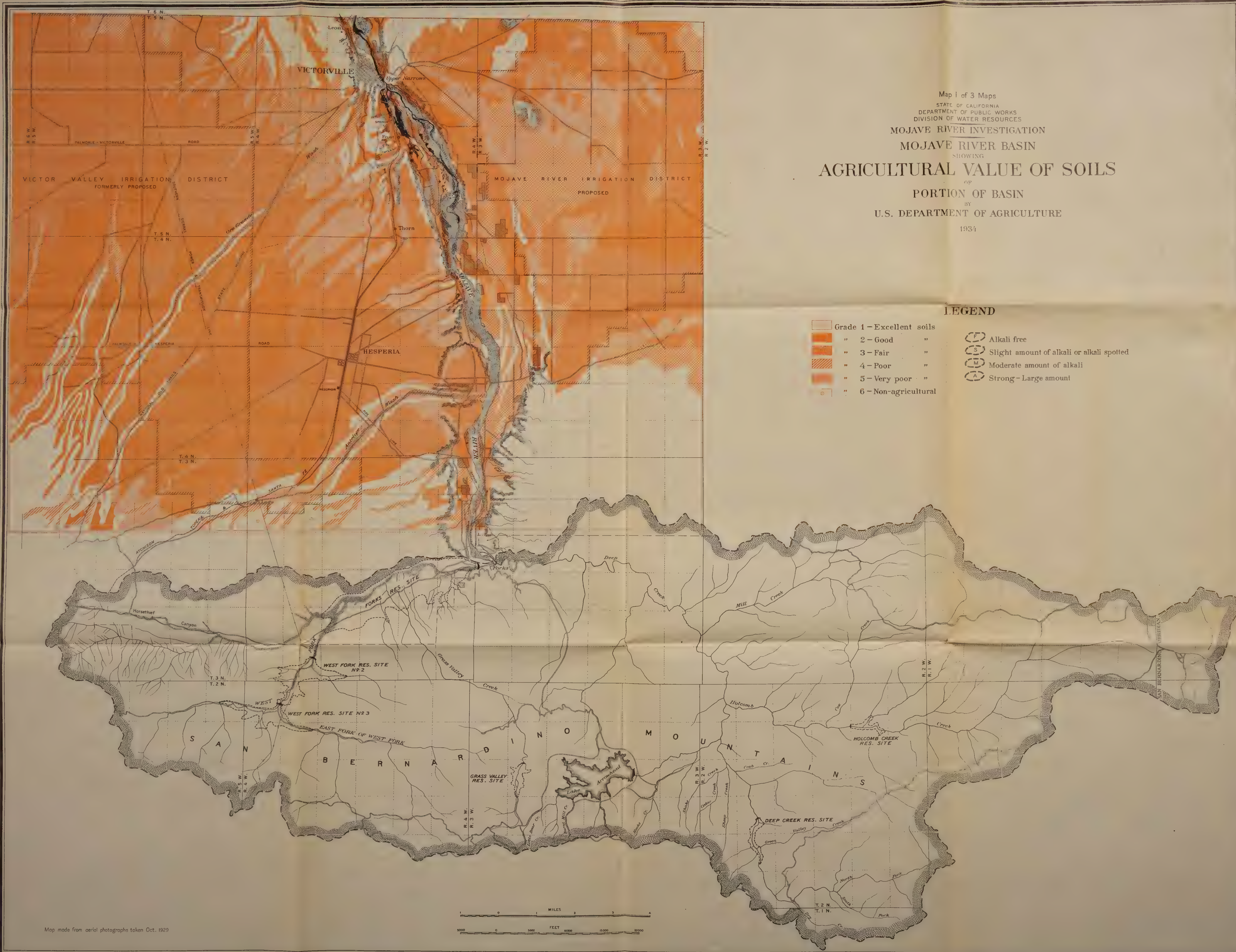
TABLE D. - Contd.

Well No. L-78 Owner: Henderson

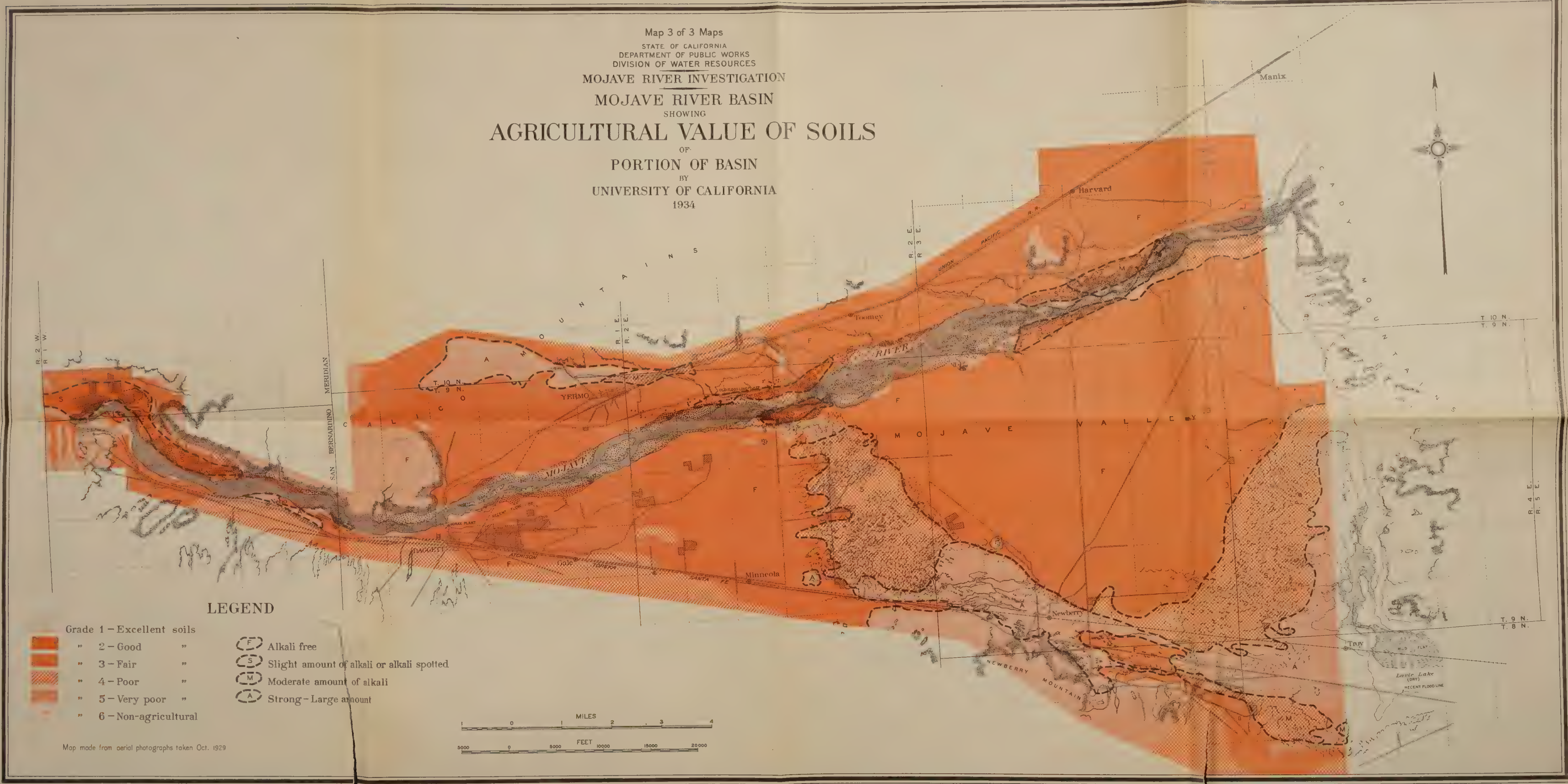
Location and description: South of center of NW¼, Sec. 34, T. 10 N., R. 3 E., S.B.B. & M.
Reference point: Top of 14-inch casing.
Elevation of reference point ("R.P."): 1774.9 feet.

Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)	Date	Dist. R.P. to water surface (Feet)
Nov. 25, 1919	12.0 1/	Sept. 24, 1931	9.8	Feb. 15, 1933	8.8
Mar. 1, 1930	8.2	Apr. 28, 1932	8.5	Feb. 14, 1934	8.9
				Jan. 30, 1935	9.1

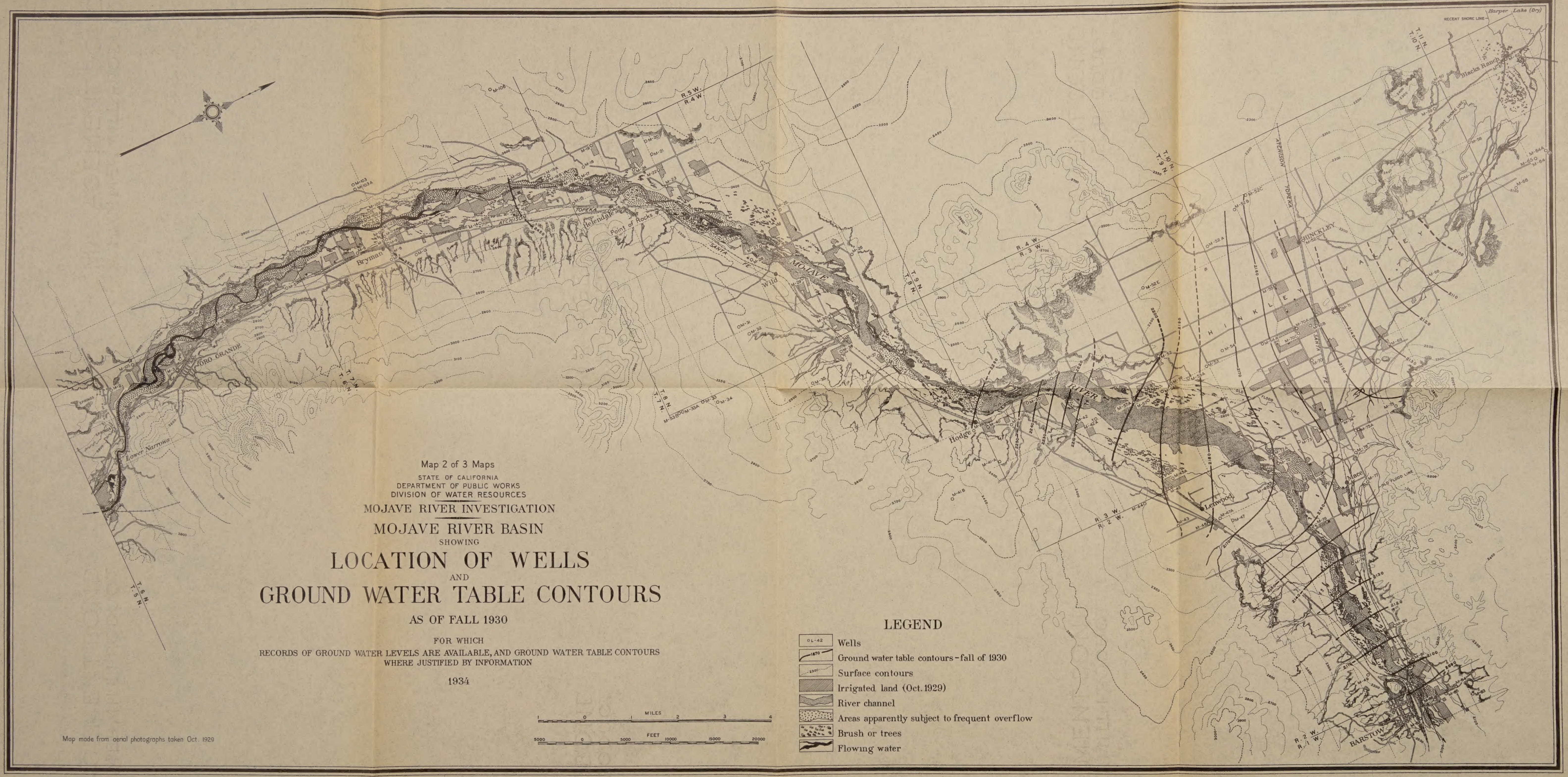
1/ Measurement from W.S. Paper 578, page 465, Well 24.

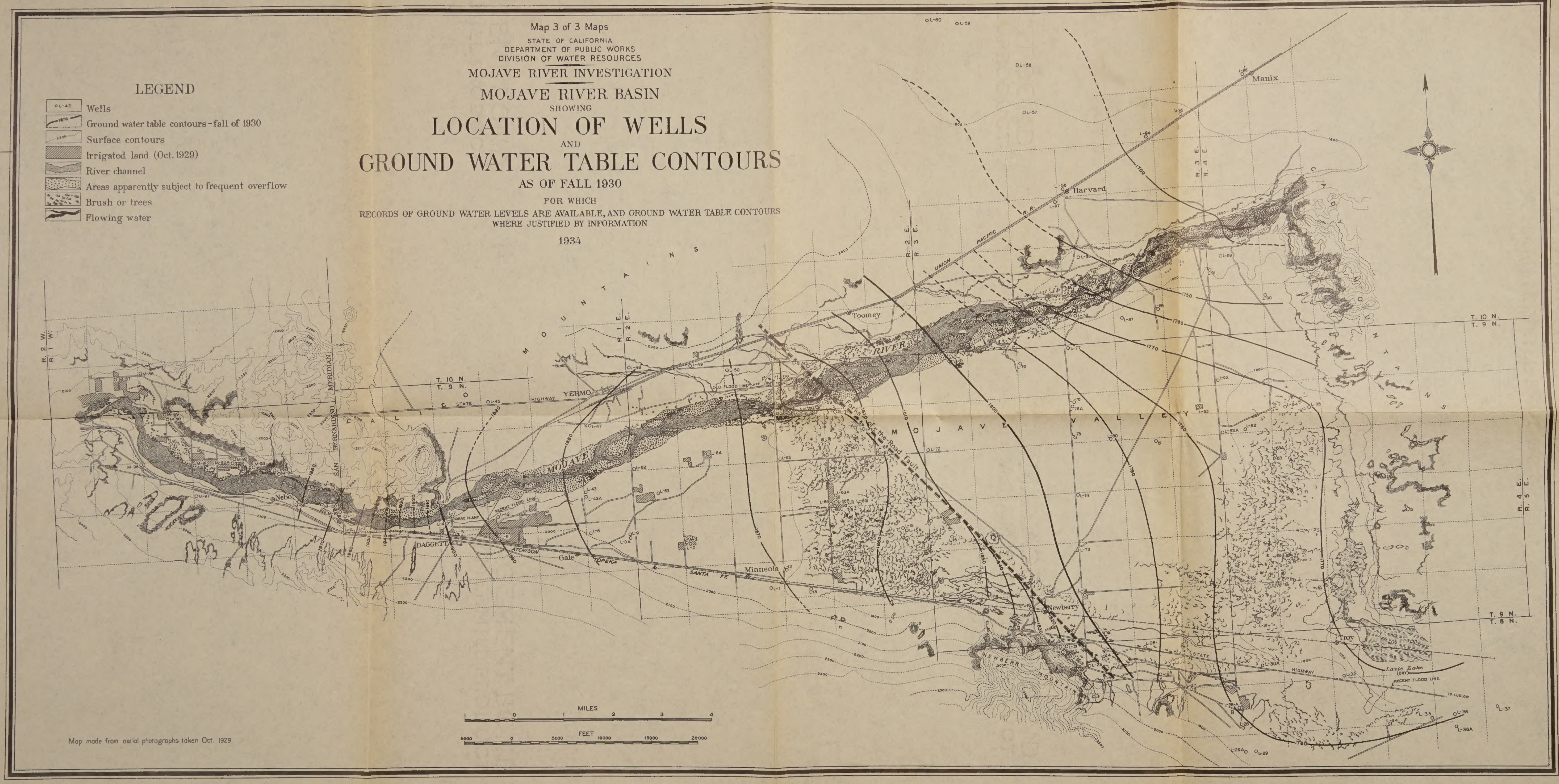

Map 1 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
AGRICULTURAL VALUE OF SOILS
OF
PORTION OF BASIN
BY
U.S. DEPARTMENT OF AGRICULTURE
1934
LEGEND
Grade 1 - Excellent soils
" 2 - Good "
" 3 - Fair "
" 4 - Poor "
" 5 - Very poor "
" 6 - Non-agricultural
Alkali free
Slight amount of alkali or alkali spotted
Moderate amount of alkali
Strong - Large amount
VICTORVILLE
HESPERIA
Thorn
Upper Narrows
VICTOR VALLEY IRRIGATION DISTRICT
FORMERLY PROPOSED
MOJAVE RIVER IRRIGATION DISTRICT
PROPOSED
PALMDALE - VICTORVILLE ROAD
MOJAVE RIVER
Forks
FORKS RES. SITE
WEST FORK RES. SITE Nº 2
WEST FORK RES. SITE Nº 3
EAST FORK OF WEST FORK
GRASS VALLEY RES. SITE
HOLCOMB CREEK RES. SITE
DEEP CREEK RES. SITE
Lake Arrowhead
Deep Creek
Mill Creek
Grass Valley Creek
Holcomb Creek
Horsethief Canyon
SAN BERNARDINO MOUNTAINS
SAN BERNARDINO MERIDIAN
T. 6 N.
T. 5 N.
T. 4 N.
T. 3 N.
T. 2 N.
T. 1 N.
MILES
FEET
Map made from aerial photographs taken Oct. 1929


Map 2 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
AGRICULTURAL VALUE OF SOILS
OF
PORTION OF BASIN
BY
UNIVERSITY OF CALIFORNIA
AND
U.S. DEPARTMENT OF AGRICULTURE
1934
LEGEND
Grade 1 – Excellent soils
" 2 – Good "
" 3 – Fair "
" 4 – Poor "
" 5 – Very poor "
" 6 – Non-agricultural
F Alkali free
S Slight amount of alkali or alkali spotted
M Moderate amount of alkali
A Strong – Large amount
MILES
1 0 1 2 3 4
FEET
5000 0 5000 10000 15000 20000
Map made from aerial photographs taken Oct. 1929
Adelanto
Oro Grande
Lower Narrows
Bryman
Helendale
Point of Rocks
Wild
Hodge
Lenwood
Barstow
Hinkley Valley
Hinkley
Mojave River
Atchison
Santa Fe
Hicks Ranch
Harper Lake (Dry)
RECENT SHORE LINE
OLD FLOOD LINE
R.5 W.
R.4 W.
R.3 W.
R.2 W.
R.1 W.
T.5 N.
T.6 N.
T.7 N.
T.8 N.
T.9 N.
T.10 N.
T.11 N.


Map 3 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
AGRICULTURAL VALUE OF SOILS
OF
PORTION OF BASIN
BY
UNIVERSITY OF CALIFORNIA
1934
LEGEND
Grade 1 – Excellent soils
" 2 – Good "
" 3 – Fair "
" 4 – Poor "
" 5 – Very poor "
" 6 – Non-agricultural
Alkali free
Slight amount of alkali or alkali spotted
Moderate amount of alkali
Strong – Large amount
MILES
FEET
Map made from aerial photographs taken Oct. 1929
Manix
Harvard
Toomey
Yermo
Daggett
Minneola
Newberry
Troy
MOJAVE RIVER
MOJAVE VALLEY
CALICO MOUNTAINS
CADY MOUNTAINS
NEWBERRY MOUNTAINS
SAN BERNARDINO MERIDIAN
UNION PACIFIC R.R.
ATCHISON TOPEKA SANTA FE
Troy Lake (DRY)
RECENT FLOOD LINE


Map 1 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
LOCATION OF WELLS
AND
GROUND WATER TABLE CONTOURS
AS OF FALL 1930
FOR WHICH
RECORDS OF GROUND WATER LEVELS ARE AVAILABLE, AND GROUND WATER TABLE CONTOURS WHERE JUSTIFIED BY INFORMATION
1934
LEGEND
Wells
Ground water table contours - fall of 1930
Surface contours
Irrigated land (Oct. 1929)
River channel
Areas apparently subject to frequent overflow
Brush or trees
Flowing water
VICTORVILLE
VICTOR RES. SITE
Upper Narrows
VICTOR VALLEY IRRIGATION DISTRICT
FORMERLY PROPOSED
MOJAVE RIVER IRRIGATION DISTRICT
PROPOSED
PALMDALE - VICTORVILLE ROAD
PALMDALE - HESPERIA ROAD
HESPERIA
Thorn
Leon
Oro Grande Wash
Antelope Wash
MOJAVE RIVER
ORD MOUNTAINS
Intake Hesperia Ditch
Deep Creek
Forks
FORKS RES. SITE
Horsethief Canyon
WEST FORK RES. SITE Nº 2
WEST FORK RES. SITE Nº 3
EAST FORK OF WEST FORK
Grass Valley Creek
GRASS VALLEY RES. SITE
Lake Arrowhead
Mill Creek
Holcomb Creek
HOLCOMB CREEK RES. SITE
DEEP CREEK RES. SITE
SAN BERNARDINO MOUNTAINS
SAN BERNARDINO MERIDIAN
T. 6 N.
T. 5 N.
T. 4 N.
T. 3 N.
T. 2 N.
T. 1 N.
R. 6 W.
R. 5 W.
R. 4 W.
R. 3 W.
R. 2 W.
R. 1 W.
MILES
FEET
Map made from aerial photographs taken Oct. 1929


Map 2 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
LOCATION OF WELLS
AND
GROUND WATER TABLE CONTOURS
AS OF FALL 1930
FOR WHICH
RECORDS OF GROUND WATER LEVELS ARE AVAILABLE, AND GROUND WATER TABLE CONTOURS
WHERE JUSTIFIED BY INFORMATION
1934
LEGEND
Wells
Ground water table contours - fall of 1930
Surface contours
Irrigated land (Oct. 1929)
River channel
Areas apparently subject to frequent overflow
Brush or trees
Flowing water
MILES
FEET
Map made from aerial photographs taken Oct. 1929
Harper Lake (Dry)
Blacks Ranch
HINCKLEY
HINKLEY VALLEY
MOJAVE RIVER
Hodge
Lenwood
Barstow
Helendale
Point of Rocks
Bryman
Oro Grande
Lower Narrows
Wild
SANTA FE
ATCHISON TOPEKA


Map 3 of 3 Maps
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
MOJAVE RIVER INVESTIGATION
MOJAVE RIVER BASIN
SHOWING
LOCATION OF WELLS
AND
GROUND WATER TABLE CONTOURS
AS OF FALL 1930
FOR WHICH
RECORDS OF GROUND WATER LEVELS ARE AVAILABLE, AND GROUND WATER TABLE CONTOURS
WHERE JUSTIFIED BY INFORMATION
1934
LEGEND
Wells
Ground water table contours - fall of 1930
Surface contours
Irrigated land (Oct. 1929)
River channel
Areas apparently subject to frequent overflow
Brush or trees
Flowing water
MOJAVE RIVER
MOJAVE VALLEY
CALICO MOUNTAINS
CADY MOUNTAINS
NEWBERRY MOUNTAINS
SAN BERNARDINO MERIDIAN
Manix
Harvard
Toomey
Yermo
Nebo
Daggett
Gale
Minneola
Newberry
Troy
Lavic Lake (DRY)
UNION PACIFIC R.R.
ATCHISON TOPEKA & SANTA FE
STATE HIGHWAY
Old Flood Line
Recent Flood Line
Borax Plant
To Ludlow
Course of the Road Fault
T. 10 N.
T. 9 N.
T. 8 N.
R. 2 W.
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
MILES
FEET
Map made from aerial photographs taken Oct. 1929